PATT-32 Proceedings

Technology Education for 21st Century Skills

Marc J. de Vries, Arien Bekker-Holtland and Gerald van Dijk (Eds.)

Table of Contents

Preface

The 32nd PATT conference was held in Utrecht, the Netherlands, August 23-26, 2016. About 80 participants brought together their experiences and ideas. The outcomes are here in this publication. We want to thank all authors who contributed and also the reviewers that helped us and the authors to bring the papers to a higher level.

We hope that these Proceedings will ne useful both for those that attended the conference and for those who were not able to be there. We lolok forward to seeing you at a next PATT conference.

September 2016

Marc J. de Vries

Arien Bekker-Holtland

Gerald van Dijk

Board of the PATT Foundation

Cooperation between primary schools and technological companies: a matter of boundary crossing

Nicole van Aar, Saskia van Oenen and Hanno van Keulen
Windesheim University of Applied Science, Zwolle/Almere, The Netherlands
TechYourFuture Centre of Expertise Techniekonderwijs
n.van.aar@windesheim.nl

Abstract

In this paper, three cases of cooperation between primary schools and technological companies are investigated from the perspective of the learning mechanisms of boundary crossing: do stakeholders learn to *identify, coordinate, reflect on* and *transform their primary processes?* We focus on authentic technological processes versus (mere) exposure to explanations or instruction, and on the development of 21st century skills. In case 1 primary school teachers were trained by experts on 3D-print technology. Both parties worked together on educational design, resulting in weekly lesson series for half a year. Case 2 describes the process of participation of teachers and students with respect to robotics and 3D-printing in order to design and create attractions for a theme park called 'WitchWorld'. In case 3, students from a teacher training college were trained by field experts on 3D-printing and on new technologies related to water management. Students designed lessons to familiarize pupils and in-service teachers with these technologies. In all three cases we focused on the development of skills and attitudes for science and technology in connection with other educational objectives of primary schools. We describe and analyse the successes and pitfalls for these forms of cooperation.

Keywords: boundary crossing, primary education, design based learning

INTRODUCTION

In the Netherlands the number of technology graduates is disappointing. The gap between education and technological practice is partly due to the fact that primary schools do not have a clear perception of what technology really is and why technology is important for children (Dutch Technology Pact, 2015). The Dutch document Education2032 (Platform Onderwijs2032, 2016), an outcome of several dialogues between educational institutes, ministry of Education, Culture and Science and the public at large, demonstrates that it is necessary to change the curriculum for primary education in such a way that young children will be trained in knowledge and skills, necessary for their lives and work in 2032 and beyond. Knowledge of technology can in theory be acquired from technological companies. The question is, how?

Schools and companies have their own different language, goals, procedures and habits. Sustainable cooperation requires that both transcend their comfort zone and learn to participate in each other's working processes. This can be seen as a process of boundary crossing (Engeström, 2001). Elaborating on this concept, Akkerman and Bakker (2011) discerned four mechanisms that can stimulate learning in boundary crossing processes: *identification, coordination*, *reflection* and *transformation*. The process of *identification* enables the parties concerned to identify similarities and differences between their organizations. This will lead to renewed insights. To allow effective *coordination* between practices, collaborators have to put effort in new or existing resources and procedures, like agreements or rubrics. Such resources and procedures are called 'boundary objects' when they preserve their inherent function in varying practices. *Reflection* may occur when cooperating parties become aware of differences in perspectives on both sides. This can be a process of perspective making (user awareness of own perspective) and perspective taking (learning to appreciate). *Transformation* comes into view when parties change their practices or create new ones.

DEFINITION OF PROBLEM

This paper reports on three recent experiences in boundary crossing between primary education and professional technological practice. We aim to contribute to the development of a theory for technology education that has impact on primary teachers and students alike with respect to their attitudes and skills for technology and design, to 21st century skills and to other important objectives of the primary curriculum. We investigate the nature and extent to which students, teachers and pupils explore or participate in authentic technological processes (e.g. manufacturing, designing, testing) and develop 21st century skills such as problem solving, critical thinking and creativity, and how this is influenced by various forms of cooperation with technological professionals. Boundary crossing may contain the process of identification, coordination, reflection and transfer. The research question that we investigate is to what extent these cases enact the four learning mechanisms.

METHODS

We explore three cases of boundary crossing. In the first case, teachers receive training from experts on 3D-printing and we focus on the success of implementing this technology in their regular classes. In this case, a boundary object (the 3D-printer) is central. In the second case, primary school students participate in the working processes of a company that designs objects for an amusement park using robotics technology and we focus on what teachers learn from observing and analyzing these activities. In this case, a school crosses the boundary of a company. In the third case, student teachers are trained by experts on 3D-printing and on water management, and we focus on the effect of this approach on professional development of the schools. In this case, companies cross the borders of the schools.

In all cases, we collected qualitative data through frequent observations, interviews, reflective and evaluative dialogues, and analysis of student reports and products.

In the scheme below we present the possible outcome for the four learning mechanisms in our three cases.

Learning mechanism	Case 1	Case 2	Case 3
Identification *(need to be different than others)*	Cooperation between workfield (Fablab instructors) and 6 primary school teachers.	Cooperation between Witchworld employees, 12 students and two primary school teachers	Cooperation between workfield and 15 students at Windesheim and on different locations
Coordination *(coherence of each other's talents)*	In collaboration with Fablab, teachers developed lesson series of 20 weeks	Lessons were designed and taught in company and at school	Collaborative esign of six lessons based on workshops.
Reflection *Create awareness for own and other people's perspective*	Teachers reflect on own process and of process Fablab and the other way around	Teachers and company director reflect on their process	Students reflect on own approach and on value of workshops given. Reactions of other people involved.
Transfer *changes will arise resulting in new roles, new practice, new education*	Cooperation leads to new lessons in school using modern technology	Both parties conserve and improve the way of collaboration: learning on location (in company) and in school	Students learn to teach science and technology with input from companies

CASE 1: 3D-PRINTING AT SCHOOL

This pilot was initiated by the municipality of Almere and the company FabLab Flevoland and executed at two primary schools (called Het Palet and Digitalis*)* with an interest in digital learning and 21st century skills.

Six teachers were trained by FabLab instructors to build their own 3D-printer and to use 3D-modelling software (SketchUp). They designed two lesson series of twenty weeks, one for students aged 6 to 8 years and one for 10 to 12 year olds. The lessons for the youngest were on basic tools and application for electronics, programming, and 3D printing (e.g. Makey Makey, BeeBot, Blokify). For the eldest, lessons aimed at enabling students to use SketchUp to design and print objects (e.g., doors, windows) to be implemented in cardboard houses. Throughout the pilot, teachers altered initial designs when tasks were too difficult for students to do in the planned way and time, when prerequisites were not in order (e.g., break down of the 3D-printer or internet access) and when FabLab-support to help with hardware en software problems was unavailable.

3D printing attracts a lot of media attention, and is supposed to be a phenomenal appetizer for schools. All the pupils and teachers in this pilot were indeed fascinated by the printer and its manifestations. They were proud to have it in their school and felt privileged as participants in the pilot In both groups, all students were very involved and devoted much more time on science and technology than usual. Students and teachers agreed that it improved affinity with modern technology. With respect to 21st century skills and other goals: teachers noted improvement in cooperation and both teachers and pupils remarked that mathematics made much more sense in this context.

However, as the lessons consisted mainly of instructions (age 6-8) and skills training (age 10-12), little attention was paid to open-ended problem solving, creativity or critical thinking. The FabLab instructors insisted on the importance of skills training: 'The only way really to develop the needed skills, it is just hard work'. Teachers depended on their professional expertise and felt uncertain to leave things more open.

Throughout this pilot, FabLab professionals and teachers reflected on the process. Teachers began to make some changes by themselves as they had doubts about the suitability of the software tools and pedagogical approach. By contrast, FabLab employees did not change perspectives but guarded the 'best approach' according to their expert thinking. The 3D-printer, as a boundary object, coordinated activities and induced a certain amount of reflection, but transformation of practices still proved difficult. The school remained unable to independently produce solutions to technological problems using 3D printing. The company still found it difficult to view their efforts as contributing to the development of cooperation skills or mathematics objectives rather than as learning others to use a 3D-printer.

Our conjecture is that it might be better to introduce children into new technologies, like 3D printing, in contexts where this technology is really useful: in a real work place. This is investigated in the next case.

CASE 2: DESIGNING AMUSEMENTPARK ATTRACTIONS

In this pilot, Witchworld, a creative company developing a new amusement park for the city of Almere, cooperated with two primary schools. Witchworld designs flying witches, medieval princes and princesses, trolls, and the like, and uses various new technologies such as robotics and 3D printing.

WitchWorld already cooperates with schools for (higher) vocational training in providing learning experiences and likes to expand their reach to primary schools. Two teachers and twelve students aged 9 to 12 year were involved. WitchWorld supplied two professionals (including the company director) to elaborate the educational design and interact with the students. Lessons were executed partly at WitchWorld and partly at the schools and involved creative thinking to solve meaningful problems. The aim of the pilot was to help the regular primary school teachers to discover their students' talents by observing them during technological problem solving.

Students should receive time and space for fantasies to emerge freely and to express them. This was achieved through tours and conversations in the WitchWorld workshop; initially as inspiration and subsequently to improve the (robotic) products that were designed and made in collaboration with WitchWorld technicians. This developed, from designs drawn on paper, and from unlimited fantasy to more technical precision. Designs were converted by technicians into 3D-prints and finished off by the students by colorful painting. The focus was on learning to construct a very simple real robot, able to make movements, by assembling the electronics and other necessary devices in a frame. Furthermore, there was room to advise WitchWorld in the production of attractions for the theme park with drawings of your own ideas for an attraction.

Pupils and teachers alike were fascinated by the WitchWorld surroundings with fairy tale objects and robots everywhere. Pupils were deeply involved in all activities, even though they were often bewildered by the appeal to their fantasy, and even though the tasks were often difficult to grasp. They felt privileged to be part of this project and would love it to be continued. In this sense, identification took place. As to teachers, they felt confirmed that this kind of collaboration can be an improvement for the school curriculum. However, the creative intentions (divergent imagination leading to the production of an object of your own design, and assisting WitchWorld in production of attractions) were only marginally realized.

The joint reflective sessions in this case were too short and too few to express and analyze reflections on the many levels involved. So, some interesting questions on the brink of coordination and transformation were now only hinted at. For example, all considered the pedagogical approach to be mainly instruction driven, even with respect to fantasize on something. The WitchWorld director commented on this as necessary to accomplish results in a short time, and as characteristic for a production company. These expressions about identity are a good start for further reflection on the complementary roles of teachers and technological professionals, but it is too little to conclude that transformation is on its way.

CASE 3: COMBINING PROFESSIONAL DEVELOPMENT WITH PRE-SERVICE TRAINING
To bridge the gap between primary education and professional practice, fifteen third year students of Windesheim teacher training college, having a science and technology profile, were trained by field experts in seven workshops based on two subjects: water management and 3D-printing. Workshops were based on learning by doing and given either at Windesheim or on location. In four of the workshops, students visited the external parties involved. Experts from *Wetsus* (European Centre of Excellence for sustainable water technology), *the faculty of Geoscience* (Utrecht University)*, RWZI Zwolle (sewage treatment), LAB21* (Windesheim innovation Centre for ICT in pedagogics and support) and *Windesheim* (teachers Science & Technology, Mechanical Engineering and researcher) all had one mission: to increase the interest of children for science and technology. In this case, students were trained in knowledge, attitude, pedagogy of inquiry and design and development of 21st century skills in order to design lessons to familiarize pupils and in-service teachers with these technologies.

According to students, the schools they visited didn't devote much time to science and technology or only used closed assignments and standard texts from school books. Most were very disappointed. Even schools that profiled themselves as science and technology schools were not familiar with the pedagogy of inquiry and design. This identification can be seen as 'othering'.

Lessons designed varied from isolated topics not related to the given workshops (e.g., on floating and sinking) to lesson series which were meaningful, challenging and stimulated curiosity. Almost all students mentioned the concepts of inquiry and design in the lessons designed and five of them described all steps of the research or design cycle separately. A lot more focused on 21st century skills (cooperation, critical thinking and communication were mentioned most). Half of the students incorporated new technologies from the workshops in their lessons, some organized an excursion or a guest speaker. The lessons designed prepared the ground for integration with other subjects such as language, math, and art.

Students observed that children were not motivated for technology lessons that consisted of reading texts and answering questions. In case these lessons included new technologies like 3D-printing or on water management, and children were able to learn by doing, making mistakes, cooperate with each other, they were motivated, asked questions, absorbed information and were very enthusiastic: "When do we get another lesson in science and technology?" Some even continued to design at home. This made the students and the in-service teachers even more enthusiastic. Students also reflected that this way of learning has advantages because other subjects can be integrated like language, math and art. On the other hand, some students indicated that children were not used to inquiry and design based learning and needed more explanation, asked for confirmation or behaved restless. Students became more aware of steps to be taken in inquiry and design, which was an explicit focus in one of the workshops. However, only five students explained the steps in their lessons designed, to make children aware.

Students experienced the workshops as very valuable and were surprised about the many different perspectives of water management. Reactions on 3D-printing varied from anxiety to enthusiasm about the unique experience. All except one considered 3D-printing as useful because of the possibilities in real life, like printing a sports shoe from recycled plastics found in the ocean. Most of them considered 3D-printing in primary school to be an added value for development of 21st century skills (*e.g.* creative thinking and cooperation) and to create a positive image of technology. At the same time, they also mentioned problems/disadvantages such as the poor quality of the printed products, price of a 3D printer, time and energy needed for printing and teachers/students who are not ready for it yet. In the end, two students still felt insecure, because of lack of knowledge about new technologies. Over all, students' ***reflection*** was hardly on the role of the companies and other institutions to overcome these problems. When reflecting, students agreed that there must be room for children to explore, ask questions, do research. According to them, the pedagogy of inquiry and design should be implemented in the curriculum. Some even want this to start from first grade in order to create a positive image of science and technology

Despite their enthusiasm, only two students dared to arrange learning situations outside the classroom using the external parties involved. Two others invited experts into the classroom. So ***transformation*** is on its way but needs to cover much more ground.

CONCLUSION:
In all cases, boundary interaction between educational institutes and external parties resulted in enthusiasm amongst pupils, students and teachers. New education material was developed and new technologies were introduced. By touching different (modern) technology as boundary crossing objects, a positive ***identification*** took place. However, the experience was not automatically translated into education materials, pedagogic approaches or products of desired quality. In all cases, cooperation between the parties involved started from a collective mission to improve technology education, but ***coordination*** was limited to practical matters, particularly with regard to scheduling. ***Reflection*** from teachers and student teachers primarily focused on their traditional role as teacher and not on their role as boundary crossers that are also responsible for solving problems like the cost of 3D printing. Companies on the other hand find it difficult to reflect on their role as co-teachers: their comfort zone is demonstrating technology and not thinking about integrating 3D printing or water management with language or math.

Transformation thus has been achieved only partly, but all parties involved are aware of this and want to continue the collaboration. Further experimenting and investigation is needed of the way schools/teachers can implement science and technology in their curriculum with support from external parties and of the role of companies as co-designers and co-teachers.

LITERATURE
Akkerman, S.F. & Bakker, A. (2011). Review of Educational Research. Boundary crossing and boundary objects. Retrieved from: http://rer.aera.net by guest on September 3, 2014.

Dutch Technology Pact 2020. (2015). Summary Dutch Technology Pact 2020. Retrieved from: http://investinholland.com/nfia_media/2015/05/Summary-Dutch-Technology-Pact-2020.pdf

Engeström, Y. (2001) Expansive Learning at Work: Toward an activity theoretical reconceptualization, *Journal of Education and Work,* 14:1, 133-156

Platform Onderwijs2032 (2016). *Ons Onderwijs2032*. Retrieved from: http://onsonderwijs2032.nl/wp-content/uploads/2016/01/Ons-Onderwijs2032-Eindadvies-januari-2016.pdf

Fostering Self-Regulated Learning (SRL) and Systematic Inventive Thinking (SIT) in Problem-Solving and Troubleshooting Processes among Engineering Experts in Industry

David Albert and Moshe Barak*
Department of Science and Technology Education,
Ben-Gurion University of the Negev, Beer Sheva, Israel
* Corresponding author
mbarak@bgu.ac.il
david.quality@gmail.com

Abstract

Study Context: The present addressed two unique aspects of fostering problem solving and inventive thinking among engineering experts: first, teaching about Self-Regulated Learning (SRL) comprised of cognition, meta-cognition and self-efficacy beliefs; and second, teaching "Systematic Inventive Thinking" (SIT) methods for problem solving.

Theoretical Background: The term self-regulated learning (SRL) is derived from Bandura's social-cognitive theory (Bandura, 1986). It involves the cognitive, meta-cognitive and self-efficacy believes aspects in learning and problem-solving. Systematic Inventive Thinking (SIT) is a method of finding solutions to problems by making systematic alterations or manipulations with a system's components and attributes, rather than searching randomly for ideas using methods such as brainstorming. The SIT method was derived from the TRIZ theory (Altshuler, 1988; Horowitz, 2001; Turner, 2009).

Methodology: The pilot study comprised observations at industry sites to learn about experts' thinking while solving problems. In the main study, we developed a 30-hour workshop on problem solving in the engineering context, which included teaching about SRL and the SIT method, including games, quizzes and practical tools of thinking and problem solving. The participants were 110 engineering experts dealing with design, manufacturing, maintenance, for example in the food industry and aviation industry. A group of 30 engineering experts from one of the organizations served as the control group. The study combined qualitative and quantitative methodologies. Data collection tools included questionnaires, interviews, tests, observations and documenting 'speaking aloud' in problem solving.

Main results: The participants significantly improved their competencies regarding identifying problems in a given system or tool, and suggesting more innovative solutions and less irrelevant solutions to these problems. They reported that their thinking had changed to become more systematic in carrying out in-depth examinations of situations, and they were more effective in searching for solutions, extracting thinking methods and taking a panoramic view of the situation.

Keywords: problem solving, inventive thinking, self-regulated learning

INTRODUCTION

Problem solving and troubleshooting are major issues in engineering and technology. Despite the huge amount of literature available in these subjects, the question of how to improve the problem solving and inventive thinking abilities of engineers, technicians or manufacturing employees continues to be of concern to researchers. The present study addressed these issues from two unique aspects: first, the role of self-regulated learning (SRL) in problem solving and inventive thinking in the engineering context; and second, the notion of teaching methods for "Systematic Inventive Thinking" to engineering experts. Self-regulated learning and creativity in problem solving are increasingly being mentioned among the skills essential for integration in complex life and work environments in the 21st century (National Research Council, 1996)

The first part of this research (pilot study) aimed at identifying aspects of SRL and inventive thinking among engineering experts in industry. The second part of the research (main research) included developing

the **E**ngineering **P**roblem **S**olving and **I**nventive **T**hinking (EPSIT) workshop, which was delivered to five groups of engineers and technicians. The study aimed at evaluating the workshop's impact on participants' use of meta-cognition and inventive thinking in engineering problem solving in the workshop and at the workplace.

LITERATURE REVIEW
Self-Regulated Learning (SRL)
In recent years, educators have recognized increasingly that the cognitive side of learning and problem solving relates closely to the meta-cognitive side, that is, a learner's self-awareness of his thinking. At the heart of the current research lies the concept of Self-Regulated Learning (SRL), which combines the cognitive, meta-cognitive and motivational aspects of learning and problem solving (Barak, 2010; Zimmerman and Schunk, 1989). While a great deal of knowledge about meta-cognition in learning among children is available, relatively little research exists regarding meta-cognitive thinking among engineering experts in industry within the context of troubleshooting and problem-solving processes.

The origin of the term Self-Regulated Learning (SRL) lies in Bandura's social-cognitive theory (Bandura, 1986), which focusses on a learner's self-observation, self-judgment and response. The theory emphasizes responsibility to the learning process (Schraw et al., 2006), recognition and use of thinking strategies and skills, and motivation to succeed (Pintrich & DeGroot, 1990). In the present study, we examined troubleshooting and problem-solving processes among industry experts, focusing on the following aspects:

- Cognition – thinking patterns of industry experts; identification of non-procedural thinking processes such as heuristics, analogies and intuition regarding professional problems in industry
- Meta-cognition – how experts in industry build a thinking strategy for troubleshooting and problem solving
- Self-efficacy – the perception of self-confidence and a sense of ability to succeed in carrying out a task

Systematic Inventive Thinking (SIT)
The term inventive thinking in engineering and technology relates to finding original and effective solutions to problems, or inventing new, useful products and services. Systematic Inventive Thinking (SIT) is a method of finding solutions to problems by making systematic alterations or manipulations with a system's components and attributes, rather than searching randomly for ideas using methods such as brainstorming. The SIT method was derived from the TRIZ theory (Altshuler, 1988; Horowitz, 2001; Turner, 2009).

Among the principles ('tools') learned in the course are:

- **Unification**: solving a problem by assigning a new use or role to an existing object
- **Multiplication**: solving a problem by introducing a slightly modified copy of an existing object into the current system
- **Division**: solving a problem by dividing an object or subsystem and reorganizing its parts
- **Change relationships between variables**: solving a problem by adding, removing or altering relationships between variables
- **Removal**: solving a problem by removing an object (with its function) from the system
- **Inversion**: solving a problem by inverting the structure or functions of components in a system

As previously mentioned, the SIT principles were learned in the EPSIT workshop addressed in this paper. Following are more details about the pilot study and the main research phases of this work.

PHASE I: THE PILOT STUDY
The pilot study intendent to identify how engineering experts such as engineers and technicians deal with troubleshooting and problem solving at the workplace, with emphasis on the aspects of cognition, meta-cognition, and the use of Declarative, Procedural, Conceptual and Qualitative (DCPQ) knowledge in problem solving.

Data collection method

In the pilot study, the researcher studied the process of troubleshooting and improving machines and production lines in a food plant. He followed the work of 22 experts (engineers, technicians and heads of production lines), and fully documented 12 cases of identifying problems and making attempts to solve them in order to learn the three aspects mentioned above, for example, identifying or comparing components, variables, processes, or checking a hypothesis. The researcher also conducted the first round of the EPSIT workshop described below, which comprised 10 meetings of three hours each (total 30 hours). Due to the limited scope of this paper, we present only one example from findings of the pilot study.

Example from findings of the pilot study: prevention of temperature measurement deviations

The temperature of a specific machine in a production line was measured using a thermocouple temperature sensor. This is an electrical device comprised of two different conductors that produces a temperature-dependent voltage as a result of the thermoelectric effect. An external quality expert who reviewed the plant's production lines identified that in one of the machines, the workers used to fold the thermocouple wires, as illustrated in Figure 1a.

The expert pointed out that folding the wires in this way might produce micro-cracks in the wires, which could influence the wires' electrical resistance and cause a deviation in the temperature measurement accuracy. A simple solution was implemented by wrapping the electrical wire around an empty spray can, as illustrated in Figure 1b.

To troubleshoot and solve this problem, the expert had to possess conceptual knowledge about electrical circuits and temperature measurements using a thermocouple, as well as qualitative knowledge about frequent faults in measuring devices. In this example, the expert deliberately searched for things that could negatively affect the accuracy or reliability of the system tested. He proposed a simple solution that used devices already existing in the close environment, with no need for adding significant resources to the system. This is one of the characteristics of inventive problem solving, as was learned in the EPSIT course developed in this research.
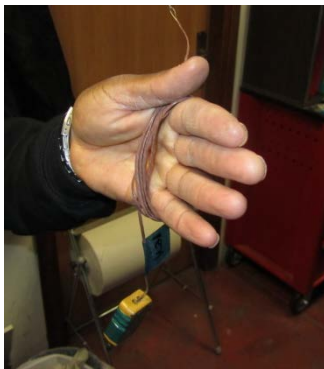
a   b

Figure 1: Wrapping an electric wire around the palm of a hand (left) or around empty spray can (right).

In the pilot study, we ran the initial version of the EPSIT course with 22 engineering experts from a food snacks factory. The findings of this phase helped in upgrading several sections of a workshop that was given later to four groups in the main study, as is reported in the following sections.

PHASE II: THE MAIN RESEARCH

The main research involved the final development, implementation and evaluation of the 30-hour **Engineering Problem Solving and Inventive Thinking** (EPSIT) workshop, which dealt with two main subjects:

1. Problem-solving methods, including the **Systematic Inventive Thinking** (SIT) method.
2. Self-regulated learning in problem solving: **cognition, meta-cognition and motivation** in problem solving.

The workshop comprised five class meetings of six hours each (total 30 hours), which included lectures, discussions, games, quizzes and an analysis of practical examples of engineering problem solving that the participants' presented from their experience in the workplace.

Data collection methods
Data were collected in the following ways:
1. Fully **documenting** students' activities in the class.
2. Administering the **Problems and Solutions** (P&S) test (see details in the following section).
3. Administering the **Awareness to Meta-Cognition Questionnaire** (Howard et al., 2000).
4. Administering the **Self-Efficacy Perception Questionnaire** (Pintrich and DeGroot, 1990).
5. Holding **interviews** with participants in the class.
6. Carrying out a **repeated examination** of the workshop's influence on the work of seven participants in their workplaces about three months after learning the course.

In this paper, we present only examples from the findings obtained in methods 1, 2, 5 and 6 mentioned above.

Example from the Systematic Inventive Thinking (SIT) course: pizza 'smart home delivery'
As previously mentioned, the core of the SIT method involves solving a problem or inventing a new product using one or a combination of the following principles: **Unification, Multiplication**, **Division**, **Change relationships between variables, Removal** and **Inversion**.

The following example demonstrates how a product or service could be improved using the principle of 'changing relationships between variables in a system.' Customers who order pizza by home delivery often complain that the pizza arrives later than promised or is not hot enough. The question is how to improve customer satisfaction. A conventional solution is to shorten delivery time, which is often expensive. According to the SIT method, we try to solve a problem using different components and processes already existing in the system, while adding a minimum of new resources. To apply the 'change relationships between variables' concept, we first make a list of all of the variables associated with the world of the problem, for example, pizza type, size, shape, delivery time and temperature. We also list the variables related to the customer, for example, residential area, distance from the pizza store, customer age or order time. The second step is to try to **add, remove or change relationships between two variables**. For example, we can link the variable "price" with the variable "delivery time," as illustrated in Figure 2.
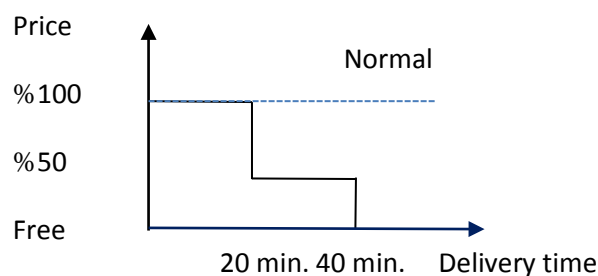
Figure 2: Linking pizza price with delivery time.

Goldenberg and Mazursky (2002) call the method illustrated in Figure 2 as change "attribute dependency," and also show the case of linking pizza price with temperature. During the course under discussion, similar examples were discussed in learning the other SIT concepts mentioned above, and the engineers were asked to present in the class examples of using these principles to solve problems at work.

For example, one of the participants presented the case of finding a root cause for an engineering problem using a 'fish-bone diagram' (Yazdani and Tavakkoli-Moghaddam, 2012) to identify all possible reasons for causing unequal thickness in aircraft parts made of composite materials (carbon and epoxy). By

analyzing each of the possibilities, the root cause was detected and a proper solution was developed. Another example was the case of improving a mechanical device aimed at locking a mechanical system. In order to provide an indication that the system is locked, an electrical switch was placed under the locking pin. This had to do with the **Unification** principle – assigning a new function to a component already existing in the system.

The nails puzzle

Some of the examples and exercises presented in the course were games and puzzles that could be found in books or on the Internet. One example is the nails puzzle shown in Figure 3, whereby the task is to hang all 10 nails from the table on the vertical nail without using any extra devices or materials.

Figure 3: The nails puzzle starting point.
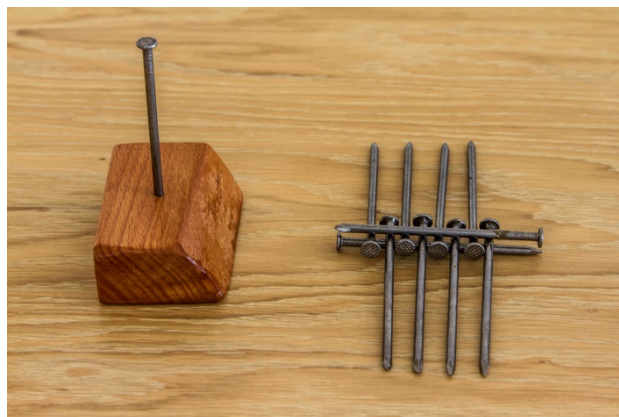
Figure 4: The nails puzzle main solution stage.

Figure 5: The nails puzzle final solution.

The participants received the nails puzzle towards the end of the workshop. They worked in groups for about 60 minutes in class. Only three out of 20 groups managed to solve the problem, as shown in Figures 4 and 5. Data on how the participants coped with the problem were obtained using the 'thinking aloud' method. We asked the participants to say in their own words what they were doing at each stage, their considerations, thoughts and trials. Three participants were recoded for 40-60 minutes each.

One of the participants in the workshop who solved the nails puzzle was a mechanical engineer who had a good record of inventiveness and problem solving in his job. Following are some quotes from what this engineer said while working on the problem:
- *The solution must follow the laws of physics*
- *It has to do with equilibrium… with symmetry*
- *There must be a construction that holds the nails*
- *A construction always includes a skeleton and supporting elements*
- *First I will create a construction and then see how to attach it to the nail*
- *I will probably use two nails for the skeleton and eight (four + four) for the body (symmetry)*
- *It must be based on action and reaction forces… the nails press against each other*
- *The nails are already connected together and pressing against each other*

Aside from his thoughts on how to solve the problem, this participant also expressed meta-cognitive ideas, such as:
- *I carried out many trials and felt that the solution was slipping through my fingers*
- *I did not have a solution in mind… I built it step by step*
- *I had a wide spectrum of thoughts… some of them were against the laws of physics*
- *I need logical thinking… how to obtain equilibrium*

The nails puzzle example demonstrates how a combination of *conceptual knowledge* in the related fields of physics and mechanics and *meta-cognitive knowledge* about problem solving play a central role in the problem-solving process. The SIT method is also relevant in solving this puzzle because SIT directs the problem solvers to use resources existing naturally in the system in a new way. In the present case, the gravity force acting on the nails is also used to press the nails together.

Findings from the Problems and Solution (P&S) test

This test intended to measure participants' ability in **identifying a problem** or dangers in using a specific tool or equipment at home or at the workplace and **suggesting solutions** to these problems. For example, in using a samovar, there are dangers of getting burned from the hot water, an electric shock or starting a fire.

The test items related to the following categories were: heating equipment, turning equipment, poisonous materials, spray work, electrical cutting tools, water reservoir, wet environment, transportation, seating, Illumination and radiation. A typical question in the test was:

a. Point out as many **problems or dangers** as possible in using the instrument.
b. Suggest as many **solutions** as possible to each problem you have mentioned.

Participants' answers were analyzed in terms of the following three aspects:

a. The **number of problems** identified for each device or tool.
b. The number of **inventive solutions**, **conventional solutions** and **irrelevant solutions** proposed for each question. This method was developed in a previous study on teaching "Systematic Inventive Thinking" to children (Barak and Mesika, 2007)
c. The **types of DPCQ knowledge** (Declarative, Procedural, Conceptual, Qualitative) used to explain the solutions a participant suggested.

The test was prepared in two versions containing 20 items each that was used as pre-and post-course exams. Half of the participants answered version 1 before learning the course and version 2 at the end of the course, and the other half answered the same exams in reverse order. Since no significant differences were observed between students' mean scores in the two versions either in the pre- or post-course exams, this indicated that the two versions were identical.

Due to the limited scope of this paper, we only present findings for questions a and b mentioned above, as shown in Table 1 and Figures 6-8.

Table 1: Number of problems, irrelevant solutions, and inventive solutions the participants suggested in the Problems and Solution (P&S) test (scale 0-100).

| | Experimental Group (N=87) | | | | Control Group (N=24) | |
| | Pre-course | | Post-Course | | | |
	Mean	SD	Mean	SD	Mean	SD
Problems identified	31.38	18.52	44.42	24.56	32.38	17.54
Irrelevant solutions	10.95	8.76	0.15	0.45	1.21	2.54
Inventive solutions	**0.65**	1.23	**4.84**	4.83	**0.14**	0.44
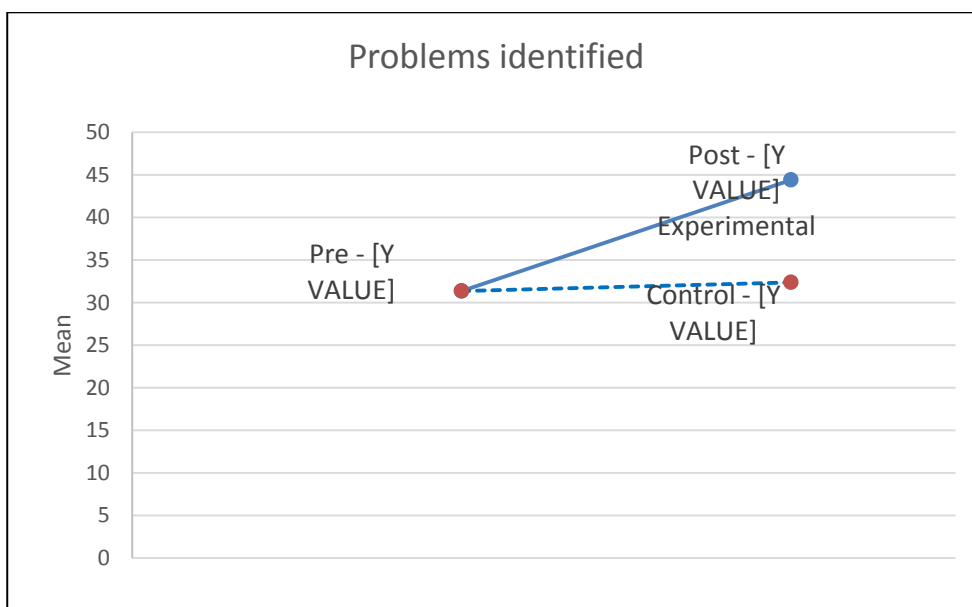
Figure 6: Number of problems identified by the experimental and control groups.
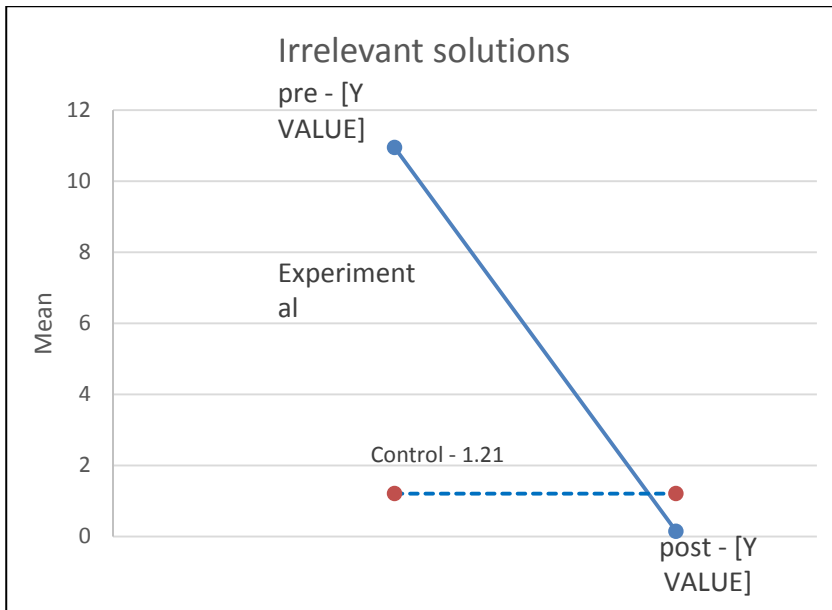
Figure 7: Number of Irrelevant suggested by the experimental and control groups.
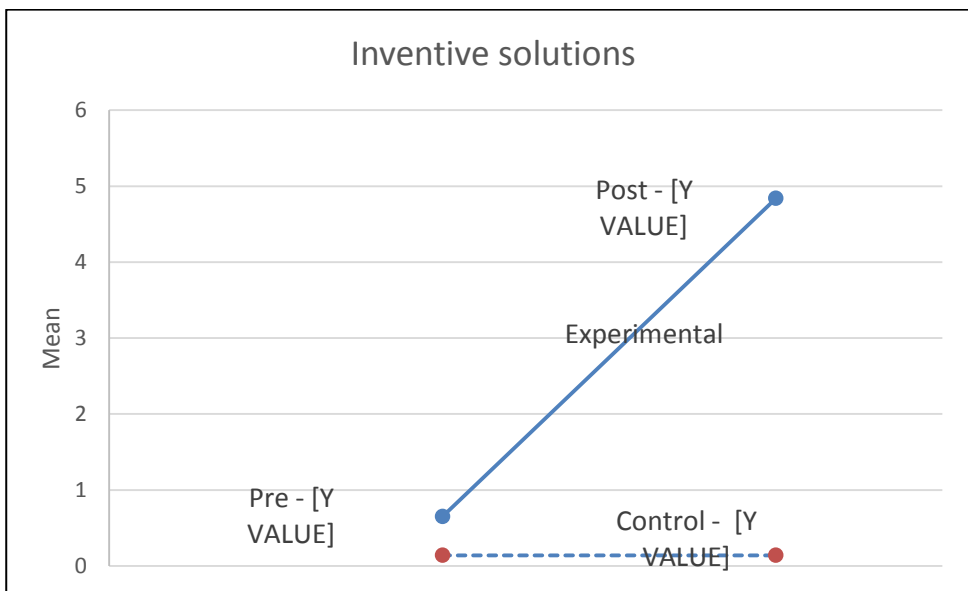
Figure 8: Number of inventive solutions suggested by the experimental control groups

Figures 6, 7 and 8 illustrate that from the pre-course exam to the post-course exam:
- The mean number of **problems** students in the experimental groups identified increased significantly from 31.38 to 44.42 (t=3.875, p<0.040)
- The mean number of **irrelevant solutions** decreased from 10.95 to 0.14 (t=11.080, p<0.000)
- The mean number of **inventive solutions** increased from 0.65 to 4.84 (t=7.75, p<0.000)

Table 1 and Figures 6-8 also illustrate that after learning the course, participants in the experimental groups excelled compared to the control group in all of the three parameters measured: the course graduates identified more problems, and suggested more inventive solutions and less irrelevant solutions to these problems.

Repeated examination of the workshop's effects on participants' performance in their workplaces three months after learning the course

Three months after the completion of each workshop, we chose four names of people randomly from each of the five groups that had participated in the workshop (total n=20) and asked them to meet the researcher at their workplace for a personal interview to discuss to what extent and how learning the EPSIT workshop affected the participant in his/her work. Twelve out of the 20 engineers who were invited accepted the invitation, but in the end the interview was held with only four, and three others sent written feedback letters of 4-6 pages. The reviewer conducted in-depth open-ended interviews, in which the interviewers selected the topics or examples they wanted to discuss. All the four oral interviews were recorded and transcribed.

In the first round of the data analysis, we identified the main categories the participants related to either in the interview or in the feedback letter. In the second round, we counted the number of participants who mentioned each category, as displayed in Table 2.

Table 2: Main categories from the subjects raised by the participants in the interviews or feedback letters three months after learning the EPSIT workshop.

Category	Frequency
Being proud of the self-change	7
Gaining sound knowledge of ideas and concepts	7
Checking problems from different directions	7
Using thinking strategies	7
Becoming confident in self-efficacy	6
Changing ways of thinking	6
Wishing to influence the workplace	5
Willing to study deeper	3

Table 2 shows that participants marked significant effects of the workshop regarding their competences and self-confidence in coping with problem solving and inventive thinking in their jobs in the workplace.

DISCUSSION AND CONCLUSIONS

The present study addressed two unique aspects of fostering problem solving and inventive thinking among engineering experts: first, teaching about Self-Regulated Learning (SRL) comprised of cognition, meta-cognition and self-efficacy beliefs; and second, teaching "Systematic Inventive Thinking" (SIT) methods for problem solving. Encouraging results were obtained in providing the **E**ngineering **P**roblem **S**olving and **I**nventive **T**hinking (EPSIT) workshop, which combined teaching SRL and SIT to five groups of engineering experts. The participants significantly improved their competencies regarding identifying problems in a given system or tool, and suggesting more innovative solutions and less irrelevant solutions to these problems. The participants reported that their thinking had changed to become more systematic in carrying out in-depth examinations of situations, and they were more effective in searching for solutions, extracting thinking methods and taking a panoramic view of the situation.

The findings of the present study replicate and extend the outcomes of prior studies that examined the effectiveness of teaching the "Systematic Inventive Thinking" (SIT) method to engineers (Barak and Goffer, 2002) and school children (Barak and Meskia, 2007). The present research, however, advanced this notion one step further by also integrating the teaching of Self-Regulated Learning (SRL), and meta-cognition in particular, in the problem-solving course. The training workshop that was developed and tested in this study could serve as a model for professional development programs not only for engineering experts but also for school students as well.

References

Altshuller, G. S. (1988). *Creativity as an exact science*. New York: Gordon and Breach.

Bandura, A. (1986). *Social foundation of thought and action*. Englewood Cliffs, NJ: Prentice Hall.

Barak, M. & Goffer, N. (2002). Fostering systematic innovative thinking and problem solving: lessons education can learn from industry. *International Journal of Technology and Design Education*, *12*(3), 227-247.

Barak, M. & Mesika, P. (2007). Teaching methods for inventive problem-solving in junior high school. *Thinking Skills and Creativity, 2*(1), 19-29.

Barak, M. (2010). Motivating self-regulated learning in technology education. *International Journal of Technology and Design Education*, *20*(4), 381-401.

Goldenberg, J. & Mazursky, D. (2002). *Creativity in Product Innovation*. Cambridge, UK: Cambridge University Press.

Horowitz, R. (2001). ASIT's five thinking tools with examples. *TRIZ Journal*, *September*.

Howard, B. C., McGee, S., Shia, R. & Hong N. S. (2000). Metacognitive self-regulation and problem solving: expanding the theory base through factor analysis. *Paper presented at the Annual Meeting of the American Educational Research Association*, New Orleans, LA.

National Research Council (1996). The national science education standards. Washington, DC: National Academy Press.

Pintrich, R. R. & DeGroot, E. F. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, 82, 33-40.

Schraw, G. & Crippen, K. J. & Hartley, K. (2006). Promoting self-regulation in science education: metacognition as part of a broader perspective on learning. *Research in Science Education*, 36, 111-139.

Turner, S. (2009). ASIT – a problem solving strategy for education and eco-friendly sustainable design. *International Journal of Technology and Design Education*, *19*(2), 221-235.

Yazdani, A. & Tavakkoli-Moghaddam, R. (2012). Integration of the fish bone diagram, brainstorming, and AHP method for problem solving and decision making-a case study. *International Journal of Advanced Manufacturing Technology*, *63*(5-8), 651-657.

Zimmerman, B. J. & Schunk, D. H. (1989). *Self-regulated learning and academic achievement: Theory research, and practice*. New York: Springer.

The relevance of indigenous technology knowledge systems (ITKS) for the 21st century classroom

Piet Ankiewicz
University of Johannesburg
South Africa
pieta@uj.ac.za

Abstract

Four categories comprising ten important skills that typify the skills necessary for the 21st century were identified by Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci and Rumble (2012). As part of their *Living in the world* category, one of the skills is *Personal and social responsibility* which includes cultural awareness and cultural competence as well as the willingness to overcome stereotypes and prejudices. Technology is embedded differently in different historical-cultural contexts. According to Onwu and Mosimege (2004:2): "Indigenous Knowledge is an all-inclusive knowledge that covers technologies and practices that have been and are still used by indigenous and local people for existence, survival and adaptation in a variety of environments …". Indigenous knowledge (IK) is social, collaborative and cultural, and may therefore serve as a vehicle to advance some of the 21st century skills mentioned.

Indigenous knowledge is often included artificially as an accessory, by means of stereotypical examples in so-called Western, discipline-based school curricula for technology. In previous research Mitcham's (1994) philosophical framework was applied to both indigenous technology knowledge systems (ITKS) and Western technology knowledge systems (WTKS), which confirmed and strengthened the complementarity between the two systems. The inclusion and integration of IK in technology lessons have however not been investigated and documented thoroughly, creating difficulties and challenges for teachers. From an ontological, epistemological, methodological and volitional perspective, the common tenets of ITKS and WTKS allow for the inclusion and integration of IK in contemporary technology curricula, rather than merely including clinical and sterile examples of IK artificially. The purpose of this paper is to investigate and develop a heuristic to assist technology teachers in including IK in their lesson planning by using Mitcham's framework, which is based on a WTKS, as point of departure. The following research question will be addressed: Based on Mitcham's four modes of the manifestation of technology, namely as object, knowledge, activity, and volition, what heuristic may be developed to assist technology teachers in including IK in lesson planning? A heuristic based on the common tenets of ITKS and WTKS has subsequently been developed and is included in this paper.

1. INTRODUCTION

Technology curricula for schools seem to be based on the institutional and formal knowledge systems generated through universities (Semali & Kincheloe, 1999), government research centres and private industry, often called the Western knowledge system (Maurial, 1999). Technology is embedded differently in different historical-cultural contexts (Idhe, 2006). Morrow (2009), who coined the term

"epistemological access", advocates the acknowledgement that Africa has its own "alternative forms of knowledge".

According to Onwu and Mosimege (2004:2): "Indigenous Knowledge is an all-inclusive knowledge that covers technologies and practices that have been and are still used by indigenous and local people for existence, survival and adaptation in a variety of environments. Such knowledge is not static but evolves and changes as it develops, and is influenced by both internal and external circumstances and by interaction with other knowledge systems. Such knowledge covers contents and contexts such as agriculture, architecture, engineering, mathematics, medicinal and indigenous plant varieties, governance and other social systems." In a similar vein, indigenous technology knowledge systems (ITKS) are all-inclusive knowledge systems, which cover technologies and their associated practices that have been and are still being used by indigenous and local people for existence, survival and adaptation in a variety of environments.

Odora Hoppers (2004) found that indigenous knowledge (IK) is often included in a clinical and sterile way in the formal curriculum, if addressed at all. Very often no IK is included, a practice that Odora Hoppers calls "knowledge apartheid". It also seems that teachers generally present only stereotyped examples, which are repeated without more ado in an examination paper (De Beer & Whitlock, 2009). Odora Hoppers (2002) points out the complementarity between indigenous and Western knowledge systems and mentions a "postmodern integrative paradigm shift", which addresses "second generation indigenization". The complementary nature of the two knowledge systems allows for "border crossings" between them. It seems that the intersection between IK and Western technology knowledge systems (WTKS) yields and denotes ITKS. This apparent complementarity between IK and WTKS in the form of ITKS requires more reflection epistemologically.

Mitcham's (1994) philosophical framework was applied in previous research (Ankiewicz, 2015a) to both ITKS and WTKS. This research confirmed and strengthened the complementarity between the two systems. The common tenets of ITKS and WTKS from an ontological, epistemological, methodological and volitional perspective allow for the inclusion and integration of IK in contemporary technology curricula, rather than merely including clinical and sterile examples of IK artificially (Ankiewicz, 2015a; Maluleka, Wilkenson & Gumbo, 2006).

Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci and Rumble (2012) analysed available curriculum and assessment frameworks for 21st century skills as well as skills that have been developed around the world. These authors identified four categories comprising ten important skills that typify the skills necessary for the 21st century. As part of the category *Living in the world*, one of the skills is *Personal and social responsibility*, which includes *cultural awareness and cultural competence*, and *the willingness to overcome stereotypes and prejudices*. Indigenous knowledge is social, collaborative and cultural (Cronje, De Beer & Ankiewicz, 2015:324) and may therefore serve as a vehicle to advance some of the above-mentioned skills. There is currently a global movement to include indigenous technological knowledge in technology curricula for schools. The current drive towards the decolonisation of curricula, especially in some developing countries, by emphasising culturally and contextually relevant contents, may further support the mentioned movement. The complementarity between ITKS and WTKS, viewed through the lens of a philosophy of (Western) technology as well as a focus on the common tenets of indigenous and Western technology from an ontological, epistemological, methodological and volitional perspective may elevate the low status of IK, and may also alleviate particular stereotypes of and prejudices towards IK. School learners are often dismissive of IK as they perceive WTKS as a tool for modernisation. They may thus experience their IK as less relevant, especially when it becomes decontextualized, for example, when they move from rural to urban areas (Maluleka et al., 2006).

The inclusion and integration of IK in technology lessons have however not been investigated and documented thoroughly, creating difficulties and challenges for teachers. The purpose of this paper is to explore and develop a heuristic, as a mental shortcut that ease the cognitive load of making a decision, to assist technology teachers in including IK in lesson planning. This will be done by using

Mitcham's framework that is based on a WTKS as point of departure. The following research question will be addressed: Based on Mitcham's four modes of the manifestation of technology, namely as object, knowledge, activity, and volition, what heuristic may be developed to assist technology teachers in including IK in lesson planning? The aforementioned point of departure is based on the belief that perspectives on one type of knowledge system may advance insight into another type of knowledge system (Maluleka et al., 2006:510).

2. A PHILOSOPHICAL FRAMEWORK OF WESTERN TECHNOLOGY KNOWLEDGE SYSTEMS AS A POINT OF DEPARTURE

The underlying theoretical framework for this paper is based on the four modes in which technology is manifested according to Mitcham (1994), namely technology as object, knowledge, activity and volition. Technological knowledge and volition, which have their origin within human beings, give rise to technological activities expressed as concrete technological objects. Ankiewicz, De Swardt and De Vries (2006) linked these four modes of manifestation of technology to the four components of general philosophy, namely ontology, epistemology, methodology and volition respectively (Figure 1).
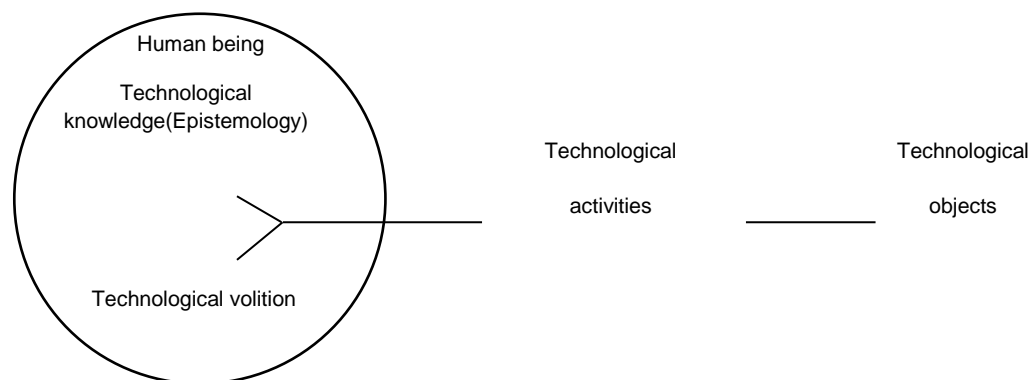
Figure 1: The modes in which technology is manifested
(Mitcham 1994:160, as adapted by Ankiewicz, De Swardt & De Vries 2006)

A fourfold set of criteria for the development and evaluation of subject curricula, based on the links made above, has previously been inferred (Ankiewicz, 2015b). These criteria have already been applied successfully to the Curriculum Assessment Policy Statement (CAPS) (Ankiewicz, 2013a) as well as the framework and learning guides for the academic majors of prospective technology education students at a local higher education institution (Ankiewicz 2015c). The use of Mitcham's modes of technology manifestation is becoming increasingly prevalent in technology education (Dagan, 2015:102; Gumaelius & Skogh, 2015:188; Schooner, Klasander & Hallström, 2015:357). The nature of IK includes philosophical components such as the ontology (what is IK?), the epistemology (ways of knowing), the methodology (methods of wisdom in action) and volition (linked to values, beliefs and attitudes of IK holders). Although it is possible to distinguish between the four aspects, they are intertwined and therefore not readily separable (Cronje et al., 2015).

2.1 Ontology

Technology as ontology is the first mode in which technology is manifested from a Western point of view (Mitcham, 1994). Any particular form of technology should possess the fundamental characteristics of technology as universal phenomenon; else it would not be technology (Van der Walt & Dekker, 1982; Van Schalkwyk, 1996). In this regard Ankiewicz (2015a) argues that a mat house (Figure 2) as a particular indigenous technology, possesses the fundamental characteristics of technology as a universal phenomenon (Ankiewicz, 2013b:4) and therefore complies with the ontological view of technology as imbedded in a Western knowledge system.

Figure 2: A mat house
(Source: Nortje 2011)

From the viewpoint of WTKS, it is clear that the mat house is a structure, more particularly a shell structure with a frame (structure). It has been uniquely constructed by humans through the manipulation of natural materials (long, light pieces of supple undressed wood and lightweight reed grass, usually the species *Scirpus* or *Cyperus*). It represents human form creation in giving form to nature by using tools (light crowbar, a mat awl and a threading-needle), to deliver a product for shelter to satisfy a human need (shelter for human purposes) (Shapera, 1930; Van der Merwe, 1945). In relation to the fundamental characteristic of technology, that it is determined by world views, IK systems are holistic and "embedded in spirituality" (De Beer & Whitlock, 2009).

2.2 Epistemology

Technology as knowledge has most frequently been the subject of analytical investigations of the epistemology or theory of knowledge (Mitcham, 1994). In technology one may, on epistemological and methodological grounds respectively, distinguish between conceptual and procedural knowledge (Ankiewicz, 2013b:4; c:3-5; 2015b:3; De Vries, 2003). Rather than regarding it as an end in itself, conceptual knowledge is used as a resource for action (APU, 1994). Western technological conceptual knowledge is discipline based (for example civil technology, mechanical technology, electrical technology, engineering graphics and design (EGD) (Ankiewicz, 2013c:7-8; 2015c). Indigenous technological conceptual knowledge is transferred orally in the form of story- telling and apprenticeships and not through textbooks, standardised tests or a classroom setting (Maxwell & Chahine, 2013). Despite the difference in transferring written discipline knowledge and oral indigenous conceptual knowledge, people still "*know that*".

Ankiewicz (2015a) illustrated the extent to which ITKS may be categorised according to De Vries's four categories of conceptual knowledge (Ankiewicz, 2013c:3) by using the *Sutherlandia frutescens* (the so-called cancer bush) as an example:

Figure 3: Sutherlandia frutescens – the 'cancer bush'
(Source: Photograph taken by Josef de Beer)

It is assumed that indigenous people know the physical characteristics of the extract made from the cancer bush. It is also assumed that they *know that* a decoction (an extract made from cancer bush) may be used to treat people suffering from cancer (knowledge of a functional nature). It is further assumed that they *know that* (a decoction of) *Sutherlandia frutescens* may assist cancer patients, since there are active ingredients in this plant that assist the immune system to fight disease (knowledge of the relationship between physical and functional nature). They may not necessarily *know that* the shrub contains an amino acid, which fights depression; pinitol, which helps patients to gain weight, and canavanine, which is successful in treating retroviruses. It is further assumed that they *know that* a specific method or procedure has to be followed when collecting and storing medicinal plant resources and preparing and administering the decoction to treat patients (process knowledge) (Van Wyk, Van Oudtshoorn & Gericke, 2002).

Master craftspeople and knowledge holders of vital IK learn primarily through apprenticeship, discipleship and systematic strategies to support memory (Maxwell & Chahine, 2013). The notion of learning through apprenticeship by these communities is specifically conducive to the acquirement of procedural knowledge that is gained through practice (Ankiewicz, 2013b:4).

2.3 Methodology

The third mode in which technology is manifested is technology as activity (Mitcham, 1994). Epistemology usually includes methodology (Van der Walt, Dekker & Van der Walt, 1985), which in particular provides insight into procedural knowledge in technology (Ankiewicz, 2013b:4; c:5; 2015b:3). Underlying the technological design process is a dimension of thinking and activity (Ankiewicz, 2013b:5). McDonald (1998) coined the thinking dimension of the technological process as the social (humanistic) elements, which are all aspects of human development. These involve not only complex thinking skills, but also the development and practice of abstract personal and social attributes such as self-esteem, motivation, self-knowledge, knowledge of people, conflict resolution, communication, leadership, coordination and networking, the ability to give and accept orders, to accept responsibility and the ability to work effectively in a team.

The above thinking activities ("minds-on") lead to doing activities ("hands-on") which are observable and hence make the technological process partly observable (Ankiewicz & De Swardt, 2002). The hands-on activities manifest as procedural stages of the technological process (Jakovljevic & Ankiewicz, 2016; Jakovljevic, Ankiewicz, De Swardt & Gross, 2004; Van Niekerk, Ankiewicz & De Swardt, 2010). McDonald (1998) coined the activity dimension of the technological process as mechanistic elements, which involve

the practical hands-on activities. Technology can therefore be regarded as both ''minds-on'' (complex thinking) and "hands-on" (practical activities) (McCormick & Davidson, 1996). The essence of technology is the interaction of mind and hand; thus inside and outside the head. Technology is dependent upon conceptual understanding, but involves more. It also involves more than a practical skill, but is dependent upon it. Ideas conceived in the mind need to be expressed in concrete form (artefacts/products) (APU, 1994). Figure 4 shows the APU model of the interaction between the mind and the hand. This interaction supports the paradigm of *Embodied, Situated, and Distributed Cognition)* (ESDC), which posits that cognitive processes are not limited to the symbolic processing of internal information structures, but are in fact embedded physiologically in action, situated in the socio-cultural world and distributed among agents, artefacts and external structures (Payette & Hardy-Vallée, 2008)**.**

THE INTERACTION OF MIND AND HAND

Imaging and modelling inside the head

Confronting reality outside the head

Hazy impressions

Discussion, drawings, sketches, diagrams, notes, grahs, numbers

Speculating and exploring

Modelling in solid to predict or represent reality

Clarifying and validating

Prototyping or provision of solutions

Critical appraisal

The potential of more developed thinking

The potential of more developed solutions

Figure 4: The APU model of the interaction between the mind and the hand
(APU, 1994)

The daily experiences of master craftspeople and knowledge holders of vital IK also demonstrate the integration of mind and hand tools that indigenous communities continually employ to conceptualise, visualise, plan and execute a myriad of activities as part of their daily practice (Maxwell & Chahine, 2013). For these craftspeople, the mind is the extension of the hand, so thinking is doing as they are immersing themselves in the creation of their arts (Maxwell & Chahine, 2013). It is clear that aspects of both the social/humanistic and mechanistic elements of the technological process are also involved in their technological activities.

Different paradigms, namely the rational problem-solving and reflective practice paradigm are the basis of design methodology (Ankiewicz, 2013b:5; c:5; 2015b:3). Master craftspeople and knowledge holders of vital IK follow the reflective practice paradigm rather than the rational problem-solving paradigm in the sense that they do not plan their design activities objectively in advance to a similar extent that Western engineers usually do. In some cases they may even design (conceptualise and visualise) and make their products merely through trial and error.

An observation that the indigenous communities in South Africa and Morocco were involved in activities by conceptualising, visualising, planning and executing (making) (Maxwell & Chahine, 2013), may be related

to the procedural stages of the technological process. The mere fact that they were conceptualising relates to the conceptual phase of design activities, which is a more subjective design activity and is therefore more adequately described by the reflective practice paradigm (Ankiewicz, 2013b:5; 2015b:3; Dorst, 1997:162).

During the idea generation stage, Western technologists generally communicate visualised ideas of their products, mainly through freehand sketches. They also usually make working drawings of their final idea during the planning stage before they start making their products. It is highly unlikely for indigenous craftspeople to communicate their ideas through sketches and drawings. They would rather have mental pictures, like the craftswomen in Morocco who have mental pictures of their carpet designs without the aid of printed patterns or pictures (Maxwell & Chahine, 2013).

Indigenous craftspeople may also plan and execute their designs (conceptualisations and visualisations) in a structured manner as part of the rational problem-solving paradigm. The fact that these communities may be unaware of their thinking processes or do not label them does not imply that they do not follow such processes. According to Stolpe and Björklund (2012:104) the implicit memory system is a sub-conscious and non-descriptive system that may be linked to procedural knowledge: Indigenous craftspeople know more than they can tell (Polanyi, 1967).

2.4 Volition

The fourth mode in which technology is manifested is technology as volition (Mitcham, 1994). Technologies are associated with a wide array of volitional activities such as drives, motivation, aspiration, intentions and choice (Ankiewicz, 2013b:6; c:5; 2015b:3; Mitcham, 1994:247). The drive underlying Western technological activity is that of improving some aspects of the made world for someone (APU, 1994).

It has been observed that the quest for survival and self-development serves as motivation for indigenous communities to execute a myriad of technological activities as part of their daily practice by applying their culturally embedded knowledge (conceptual technological knowledge) and competencies (procedural knowledge and skills) (Maxwell & Chahine, 2013). This also relates to some of the previously mentioned social (humanistic) elements of the technological process from a methodological perspective.

3. DISCUSSION AND HEURISTIC

The complementary nature and common tenets of ITKS and WTKS have made it possible to adapt the fourfold set of criteria for the development and evaluation of the intended technology curricula to serve as guidelines (Ankiewicz, 2015c) in assisting technology teachers to select IK as lesson contents in advancing the 21st century skill under discussion. These guidelines are:

From an **ontological** (O) point of view technology teachers should first ascertain whether the indigenous technology they intend to include explicitly (O3) in their lessons possesses the fundamental characteristics of technology as a universal phenomenon (O2) and therefore qualifies ontologically as genuine and true technology (O1). [The symbols between brackets refer to the specific criteria that were mentioned in a previous paper - refer to Ankiewicz (2015c).]

Epistemologically (E), technology teachers should distinguish between conceptual knowledge ("knowing that") and procedural knowledge ("knowing how") attached to the specific indigenous technology they intend to teach. They should be aware that indigenous technological conceptual knowledge is usually oral and not written like Western technological conceptual knowledge. Indigenous communities acquire indigenous technological procedural knowledge (E6) through apprenticeship which is activity based (M3). Teachers should emphasise both conceptual and procedural indigenous technological knowledge (E2) in a balanced way (E3) in their lessons.

Methodologically (M), indigenous technology is also activity based (hands-on activities with mechanistic elements) which allows technology teachers to identify and emphasise these activities explicitly in their lessons (M3). Teachers should be aware that indigenous technology, unlike Western technology, relies more on the reflective paradigm than on the rational problem-solving paradigm (M2). Subsequently, framing the teaching of indigenous technology to a stage model (M1) may not necessarily be feasible. However, there are some instances in which planned activities point towards the rational problem-solving paradigm, although to a lesser extent than is the case with Western technology (M1). Even though these communities may not be aware of these, ITKS also involve complex thinking processes that technology teachers may identify and emphasise in their lessons when teaching complex thinking skills (M4; V2). A paradox facing technology teachers is to include the implicit procedural knowledge, on which ITKS rely heavily, in an explicit way in lessons.

In terms of **volition** (V), teachers should emphasise that the quest for survival and self-development serves as motivation (social/humanistic elements) for the daily technological activities of indigenous communities, as opposed to improving some aspects of the made world for someone (V1). Volition must in technology lessons be integrated with the ontology, epistemology and methodology of technology (V1). No one can do (methodology) technology (ontology) without knowing (epistemology) and without the desire to do so (volition) (Ankiewicz, 2013b:7; Ankiewicz, Van Rensburg & Myburgh, 2001:95).

Based on the guidelines above, the following heuristic (Table 1 below) has been developed to assist technology teachers in selecting IK as lesson contents in advancing the 21st century skill *Personal and social responsibility,* particularly cultural awareness and cultural competence, and the willingness to overcome stereotypes and prejudices. Teachers should start with the column on the left-hand side of Table 1, and first ascertain whether the indigenous technology they intend to include in their lessons qualifies **ontologically** (O, in the first column) as genuine and true technology. Thereafter, they may analyse the indigenous technology they intend to teach **epistemologically** (E, in the second column), **methodologically** (M, in the third column) and **volitionally** (V, on the right-hand side).

It is evident from a philosophical perspective that technology teachers should focus on the common tenets of ITKS and WTKS, rather than merely include sterile examples of IK in technology lessons. The heuristic will assist technology teachers to account for the complementarity between ITKS and WTKS when deciding on the inclusion of IK in lessons. Unfortunately, due to space restriction, it is not possible to give an example of its application in this paper.

Table 1: A heuristic to assist teachers in selecting indigenous technology as lesson contents

Ontology (O)	Epistemology (E)	Methodology (M)	Volition (V)
O1. For particular indigenous products/artefacts that you intend to include in your lessons, first ascertain whether they possess the following fundamental characteristics of technology as universal phenomenon. The indigenous product/artefact is: 1. a phenomenon unique to **humans;** 2. employed by **using tools**; 3. a way of human **form creation;** 4. giving form to **nature;** 5. for **human purposes**; 6. to deliver a **product or process**; 7. **being determined by world views;** it is **holistic "and embedded in spirituality**" (De Beer & Whitlock, 2009).	**Conceptual knowledge ("knowing that")** E1. Emphasise that the indigenous technology that you intend to teach is: 1. not discipline based; 2. transferred orally (storytelling and apprenticeships). E2. Despite indigenous technology not being discipline based, relate the conceptual knowledge with regard to particular indigenous products/artefacts to the three main strands/themes of technological conceptual knowledge (i.e. structures, materials processing, control systems). E3. Relate the conceptual knowledge with regard to the indigenous product/artefact to De Vries's (2003) four categories of conceptual	**Procedural knowledge ("knowing how")** M1.For particular indigenous products/ artefacts that you intend to teach, identify and emphasise the interactive process between the mind (minds-on activities) and hand (hands-on activities) that master craftspeople follow by identifying their thinking processes and skills as well as their practical activities. M2.Emphasise that master craftspeople and knowledge holders of vital IK: 1. acquire indigenous technological procedural knowledge (also the use of tools) through apprenticeship which is activity based; 2. follow the reflective practice rather than the rational problem-solving paradigm; 3. conceptualise their ideas in a more subjective way and is,	V1. Emphasise that the quest for survival and self-development serves as motivation (social/humanistic elements) for the daily technological activities of indigenous communities as opposed to improving some aspects of the made world for someone. V2. Volition must be integrated with the ontology, epistemology and methodology of technology. Indicate how the quest for survival and self-development serves as motivation (social/humanistic elements) for the daily technological activities (methodology) and knowledge (epistemology) of indigenous communities.

	knowledge:	therefore, more adequately
	1. knowledge of a physical nature;	described by the reflective practice paradigm;
	2. knowledge of a functional nature;	4. communicate their ideas through mental pictures rather than freehand sketches and drawings;
	3. knowledge of the relationship between physical and functional nature;	5. do not necessarily plan and execute/make their ideas in a planned manner;
	4. process knowledge.	6. apply complex thinking processes and skills (creative and critical thinking, decision-making, problem solving and design) sub-consciously.
	E4. Identify any normative judgements that master craftspeople and knowledge holders of vital IK might have about the indigenous product/artefact (whether it functions well or not).	

4. REFERENCES

Ankiewicz, P.J. (2013a). The alignment of the CAPS for technology in the senior phase with the philosophy of technology: a critical analysis. Conference proceedings of the *ISTE International Conference on mathematics, science and technology education: "Towards effective teaching and meaningful learning in mathematics, science and technology",* Mopani camp, Kruger National Park, 21-24 October 2013, 13-25.

Ankiewicz, P. J. (2013b). 'n Teoretiese besinning oor die implikasies van die filosofie van tegnologie vir klaskamerpraktyk. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie,* 32(1), Art.#386, 9 pages. Retrieved June 13, 2013 from http://dx.doi.org/10.4102/satnt.v32i1.386.

Ankiewicz, P.J. (2013c). 'n Teoretiese besinning oor die implikasies van die filosofie van tegnologie vir onderwyseropleiding. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie,* 32(1), Art. #387, 9 pages. Retrieved June 18, 2013 from http://dx.doi.org/10.4102/satnt.v32i1.387.

Ankiewicz, P.J. (2015a). Inheemse en Westerse tegnologiese kennisstelsels: Twee kante van dieselfde muntstuk?, *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie* 34(1), Art. #1309, 7 pages. http://dx.doi.org/10.4102/satnt.v34i1.1309.

Ankiewicz, P.J. (2015b). 'n Teoretiese besinning oor die implikasies van die filosofie van tegnologie vir kriteria vir vakkurrikulumontwikkeling en -evaluering', *Suid- Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie* 34(1), Art. #1170, 7 pages. http://dx.doi.org/10.4102/satnt.v34i1.1170.

Ankiewicz, P.J. (2015c). The implications of the philosophy of technology for the academic majors of technology student teachers. Conference proceedings of the Pupils' Attitudes towards Technology (PATT) 29th International Conference, Marseille, France, 7-10 April, 2015, 13-25.

Ankiewicz, P.J., & De Swardt, A.E. (2002). *Aspects to be taken into account when compiling learning programmes to support effective facilitation of Technology Education*. Conference proceedings of the National Conference for Technology Teachers, Port Natal School, Durban, 30 September-1 October 2002, 76-81.

Ankiewicz, P.J., De Swardt, A.E., & De Vries, M. (2006). Some implications of the philosophy of technology for science, technology and society (STS) studies. *International Journal of Technology and Design Education,* 16(2), 117-141.

Ankiewicz, P., Van Rensburg, S., & Myburgh, c. (2001). Assessing the attitudinal technology profile of South African learners: A pilot study. *International Journal of Technology and Design Education,* 11(2), 93-109.

Assessment of Performance Unit (APU) (1994). *Learning through design and technology* (pp. 59-67). In F. Banks (Ed.). Teaching technology. London & New York: Routledge.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In Griffin, P., Care, E., & McGaw, B. Assessment and teaching of 21st century skills, Dordrecht, Springer.

Cronje, A., De Beer, J. & Ankiewicz, P. (2015). The development and use of an instrument to investigate science teachers' views on indigenous knowledge. *African Journal of Research in Mathematics, Science and Technology Education,* 19(3), 319-332.

Dagan, O. (2015). Kindergarten student teachers' attitudes towards and perceptions of technology: The impact of a one-year pre-service course. Conference proceedings of the Pupils' Attitudes towards Technology (PATT) 29th International Conference, Marseille, France, 7-10 April, 2015, 98-105.

De Beer, J.J.J. & Whitlock, E. (2009). Indigenous Knowledge in Life Science classroom: Put on your De Bono hats! *The American Biology Teacher*, 71(4), 209 - 216.

De Vries, M.J. (2003). The nature of technological knowledge: Extending empirically informed studies into what engineers know. *Techné: Research in Philosophy and Technology,* 6(3), 1–21.

Dorst, K. (1997). *Describing design*. PhD thesis, Technische Universiteit Delft, Delft.

Gumaelius, L. & Skogh, I-B. (2015). Work plans in technology: A study of technology education practice in Sweden. Conference proceedings of the Pupils' Attitudes towards Technology (PATT) 29th International Conference, Marseille, France, 7-10 April, 2015, 188-194.

Payette, N., & Hardy-Vallée, B. (2008). Beyond the brain: Embodied, situated and distributed cognition.

Ihde, D. (2006). *The designer fallacy and technological imagination* (pp.121-131). In J.R. Dakers (Ed.). Defining technological literacy: Towards an epistemological framework. New York: Palgrave Macmillan.

Jakovljevic, M. & Ankiewicz, P. (2016). Project-based pedagogy for the facilitation of webpage design. *International Journal of Technology and Design Education*, 26(2): 225-242. http://dx.doi.org/10.1007/s10798-015-9312-5.

Jakovljevic, M., Ankiewicz, P., De Swardt, A.E., & Gross, E. (2004). A synergy between the technological process and a methodology for web design: Implications for technological problem solving. *International Journal of Technology and Design Education*, 14, 261-290.

Maluleka, K., Wilkinson, A., & Gumbo, M. (2006). The relevance of indigenous technology in Curriculum 2005/RNCS with special reference to the Technology Learning Area. *South African Journal of Education*, *26*(4), 501-513.

Maurial, M. (1999). Indigenous knowledge and schooling: *A continuum between conflict and dialogue* (pp. 59-77). In L.Semali, & J. Kincheloe (Eds.). What is indigenous knowledge? Voices from the academy. NY, New York: Falmer Press.

Maxwell, K. L. H., & Chahine, I. C. (2013). Cultural immersion and mathematics teacher education: Explorations in Morocco and South Africa. *Journal of Humanistic Mathematics*, 3(2), 62 - 75.

McCormick, R., & Davidson, M. (1996). Problem solving and the tyranny of product outcomes. *Journal of Design and Technology Education*, 1(3), 230-241.

McDonald, M. A. (1998). *The social component of the technological process and interdisciplinary-integrated studies*. M.Ed. dissertation, Rand Afrikaans University, Johannesburg.

Mitcham, C. (1994). *Thinking through Technology.* Chicago: The University of Chicago Press.

Morrow, W. (2009). Bounds of democracy: Epistemological access in Higher Education. Retrieved from: http://www.hsrcpress.ac.za

Nortje, J.M. (2011). *Medicinal ethnobotany of the Kamiesberg, Namaqualand, Northern Cape Province South Africa*. M.Sc. dissertation, University of Johannesburg.

Odora Hoppers, C.A. (2002). *Indigenous knowledge and the integration of knowledge systems: Towards a philosophy of articulation*. New Africa Books.

Odora Hoppers, C.A. (2004). *Culture, Indigenous Knowledge and development: The role of the university*. March, Occasional Paper No. 5, Centre for Education Policy Development. Braamfontein, Johannesburg.

Onwu, G & Mosimege, M. (2004). Indigenous knowledge systems and science and technology education: A dialogue. *African Journal of Research in SMT Education*, 8(1), 1–12.

Polanyi, M. (1967). The tacit dimension. 1967. *Garden City, New York*, *217*.

Schooner, P., Klasander, C. & Hallström, J. (2015). Swedish teachers' views of assessing technological systems in compulsory school. Conference proceedings of the Pupils' Attitudes towards Technology (PATT) 29th International Conference, Marseille, France, 7-10 April, 2015, 357-363.

Semali, L., & Kincheloe, J. L. (1999). *What is indigenous knowledge?: Voices from the academy*. NY, New York: The Falmer Press.

Shapera, I. (1930). *The Khoisan peoples of South Africa. Bushmen and Hottentots*. London: Routledge and Kegan Paul Ltd.

Stolpe, K., & Björklund, L. (2012). Seeing the Wood for the Trees: Applying the dual-memory system model to investigate expert teachers' observational skills in natural ecological learning environments. *International Journal of Science Education*, *34*(1), 101-125.

Van der Merwe, P.J. (1945). *TREK. Studies oor die mobiliteit van die pioniersbevolking aan die Kaap*. Kaapstad: Nasionale Pers Beperk.

Van der Walt, J.L. & Dekker, E.I. (1982). *Fundamentele opvoedkunde vir onderwysstudente*, Silverton: Promedia Publikasies.

Van der Walt, J.L., Dekker, E.I., & Van der Walt, I.D. (1985). Die opvoedingsgebeure: 'n Skrifmatige perspektief. Potchefstroom: Instituut vir Reformatoriese Studies.

Van Niekerk, E., Ankiewicz, P., & De Swardt, E. (2010). A process-based assessment framework for technology education: A case study. *International Journal of Technology and Design Education,* 20(2), 191-215.

Van Schalkwyk, P. (1996). Opvattinge oor tegnologie by leerlinge en onderwysers. Unpublished doctoral thesis, Potchefstroom University for Christian Higher Education, Potchefstroom.

Van Wyk, B.-E., Van Oudtshoorn, B. & Gericke, N. (2002). *Medicinal plants of South Africa*. Pretoria: Briza Publikasies.

Developing 21st century skills among undergraduate student teachers

Francois van As
University of Johannesburg
South Africa
fvanas@uj.ac.za

Abstract

By involving our technology student teachers in activities that are authentic to technological practice, as teachers they will be able to provide stimulating and relevant learning for learners (Turnbull, 2002) which have to include 21st century skills that enable them to develop minds and responsibility for the future (Snape & Fox-Turnbull, 2013).

Technology student teachers at a South African university enroll for two academic majors, as requirement for a four-year undergraduate degree in technology. A fourfold set of criteria, developed by Ankiewicz (2015b), was applied to the first four semester modules of the academic major Engineering Graphics and Technology Education (EGTE). It was found that there was a strong emphasis on conceptual knowledge with a concern whether there were sufficient opportunities for practicing procedural knowledge. At the time of this evaluation the sixth semester module has not yet been implemented. Ankiewicz (2015b) anticipated that it might address these concerns as this module (EGTE 3B) was designed as a project-based module aimed at aspects of authentic technological practice. EGTE 3B expects students to solve real-world technological problems with a final assessment opportunity to solve such a problem.

However, after the first year of offering EGTE 3B, and although it has been designed to developed students' procedural knowledge, including the 21st century skills, we do not know the extent to which it succeeds in doing so. The purpose of the research was to determine the extent to which this module succeeds in developing student teachers' procedural knowledge. A qualitative study (Merriam, 1998) was conducted by which data was collected through the analysis of students' portfolios and open-ended questionnaires. The main finding was that the module succeeded satisfactorily in improving students' procedural stages, but to a lesser extent to complex thinking that also relates to 21st century skills.

Keywords

Technology education, technological process, procedural knowledge, 21st century skills

Introduction

"… life in the 21st century has become international, multicultural and inter-connected, new skills are needed to succeed in education and in the workplace."
(Suto & Eccles, 2014, p.2)

Students of the 21st century need more than just the core subjects offered at school. They need to know how to use their knowledge and skills by applying different thinking processes, applying knowledge to new situations, analysing information, comprehending new ideas, communicating, collaborating, solving problems, and making decisions (Salpeter, 2008).

This gave rise to the idea that students need 21st century skills to be successful. According to Rotherham and Willingham (2010) these are not new, for example, critical thinking and problem solving but have been part of human progress throughout history. Changes in our economy and the world mean that collective and individual success depends on having such skills.

One way of bringing the complexity of real-life, situated context into the classroom is to link problem-solving to projects needed in the community (Hill, 1998). By involving our students in such projects we expose them to activities that are authentic in terms of technological practice. According to Lombardi (2007), authentic learning typically uses problem-based activities which focus on real-world, complex problems and their solutions. Authentic learning goes beyond content to bring into play multiple disciplines, multiple perspectives, ways of working, habits of mind, and community. Technology education lends itself well to authentic learning by which we expect learners to solve real-world problems.

21st century skills

Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci and Rumble (2012) identified ten important 21st century skills from the analysis of curriculum and assessment frameworks for 21st century skills developed around the world. These can be grouped into four broad categories, namely (i) ways of thinking, (ii) ways of working, (iii) tools for working, and (iv) living in the world.

Technology education

Technology at school level is globally still a developing subject with no equivalent academic discipline from which curriculum development and classroom pedagogy may occur (Ankiewicz De Swardt & De Vries, 2006; De Vries, 2001; De Vries, 2003). Within this context, even though this research focused only on one specific major offered at a specific university it might be of interest to the wider international technology fraternity providing some insight into the factors to consider when developing an academic major for technology student teachers.

Technology education is the actual teaching of technology by which the learners are given the opportunity to design, make and evaluate a product in response to a need or want. The purpose of technology education in South Africa is to contribute towards learners' technological literacy by giving them opportunities to learn and understand technological knowledge and to develop and apply specific skills to solve technological problems (Department of Education, DoE, 2002).

According to McCormick (1997), technological knowledge consists of *conceptual knowledge* ('knowing that'), which refers to the relationships among 'items' of knowledge and *procedural knowledge* ('knowing how') which distinguishes different levels of procedure when solving technological problems. When practising technology these two types of knowledge cannot be separated. Procedural knowledge consists of two dimensions, a thinking dimension and an activity dimension (Ankiewicz, 2013b). According to Jakovljevic and Ankiewicz (2016) it is common in technology to present the procedural knowledge of technology in a stage-oriented format in models. Most models of the technological process indicate a linear progress, assuming that the process is completed in a particular sequence. For educational purposes we use a stage model which is based on the paradigm of rational problem-solving and which may serve as explicit organisational framework for the teacher and learner to be used to provide learners with the opportunity to develop procedural knowledge through practice (Ankiewicz, 2015a & b). The procedural stages of the technological process are: statement of the problem; design brief; investigation; proposal; initial ideas; research; development; planning; realisation/making; testing, evaluation and improvement (Jakovljevic & Ankiewicz, 2016). Each procedural stage of

the technological process requires the application of some of the sub-processes of complex thinking, namely, creative and critical thinking, decision-making, problem-solving and design (Ankiewicz, 2013a), which correspond to a great extent to the 21st century skills mentioned under 'ways of thinking' (Binkley et al., 2012).

At the university concerned, student teachers enrol for two majors as part of a four-year undergraduate degree, namely Engineering Graphics and Technology Education (EGTE), up to third-year level, including six semester modules and Civil Technology up to second year level, including four semester modules. The first five semester modules for EGTE aimed to equip student teachers with the necessary knowledge and skills to enable them to successfully complete the sixth and final module (EGTE 3B), which can be regarded as the key module of the BEd. programme. Table 1 shows the Curriculum framework for Engineering Graphics and Technology Education, with the purpose and a brief description of the content of each module.

EGTE 3B is a project-based module which spans over 13 weeks and which involves two design projects, namely, one in Civil Technology (6 weeks) and one in Mechanical Technology (6 weeks). Table 2 shows part of the learning guide for EGTE 3B, indicating the themes and assessment criteria for a design project in Civil Technology. The final assessment opportunity of EGTE 3B was in the form of a practical assessment task (PAT) which simulates authentic, real-life problem solving. Each student has to prepare a design portfolio as part of their assessment in which they documented each stage of the technological process they followed to solve an authentic or real-life problem, need or want. Instructions to the students were to read the project brief carefully and follow all the procedural stages of the technological process, excluding the making stage. All research evidence had to be included in their design portfolios.

The project brief that precedes the task reads as follows:
You are a designer for a cell phone accessories company. You are commissioned to design a Perspex stand for a specific cell phone which will be used to display the phone on the shelves of the company's shops. Use your own cell phone as reference to design the stand.

Although examples of cell phone stands made of Perspex can be found on the Internet the purpose of the activity was not to complicate the problem to be solved but to give the students an opportunity to experience the application of the technological process in a real-life situation.
It was expected students would firstly identify the problem, formulate the design brief then search for certain information they would need before they could come up with a proposal on how they intend to solve the problem. Such information would include knowledge about Perspex which might influence the design of the product, e.g., properties of the material and how to process the material. They also had to determine the dimensions of their own cellular phones as their designs would be based on these. After gathering the necessary information they had to describe exactly what they intended to design. The next stage expected from them was to develop ideas. During this creative stage the students had to put their ideas on paper in the form of freehand sketches. The different ideas were weighed up in terms of their advantages and disadvantages by means of critical analysis. Eventually, the students will have to select one idea to be developed further. If there were particular aspects of their chosen ideas which were problematic, in the sense that the students were unsure how to handle them, they had to find answers to those problematic aspects by further research. This research implies a more in-depth and focussed search for information than during their initial investigation. Research is conducted to solve problems and answer questions relating to the problematic aspects of the chosen idea in order to develop it into a workable solution. Once the students had resolved all the problematic aspects of their chosen ideas they had to develop their final ideas. The next stage expected the students to formulate plans on how the product might be manufactured. During the planning stage they

had to draw working drawings (drawn to scale and including measurements) by using drawing equipment or Computer Aided Drawing (CAD). The final stage expected them to evaluate their final designs. Here students were supposed to use certain given criteria, namely physical properties, construction, function, aesthetics and value to evaluate their designs. Following the evaluation of their designs it might be expected that they do further design work to improve it or even to redesign the product.

Ankiewicz (2015b) developed a fourfold set of criteria for the evaluation of the intended curriculum. These were applied to the first four semester modules of the academic major EGTE. It was found that there was a strong emphasis on conceptual knowledge with a concern whether there were sufficient opportunities for practicing procedural knowledge. At the time of this evaluation the sixth module has not yet been implemented. Ankiewicz (2015b) anticipated that the sixth module EGTE 3B might address these shortcomings.

Problem statement and purpose of study

However, after the first year of offering EGTE 3B, and although it has been designed to developed students' procedural knowledge, including the 21st century skills, we do not know to what extent it succeeds in doing so.

The purpose of the research was to determine to what extent the module EGTE 3B succeeds in developing student teachers' procedural knowledge, including 21st century skills.

The research question that underpinned this research was: To what extent did the module EGTE 3B succeeded in the development of student teachers' procedural knowledge, including the 21st century skills?

Methodology

Following from the purpose of the research as well as the nature of the research question a qualitative research approach was followed. Convenient sampling was used, which included six third-year students (three male and three female) enrolled in a four-year undergraduate degree in Technology Education. The research focused on the third-year academic module, namely EGTE 3B. Data was collected through the analysis of students' design portfolios' (artefact) which were prepared for their final assessment opportunity (PAT) as well as open-ended questionnaires completed by the students regarding their experiences of their final assessment opportunity.

Students' design portfolios were assessed by using an analytic type of scoring rubric to assess the various procedural stages of the technological process. The equal weightings for the various stages in the existing rubric, which was developed for junior secondary school students (Ankiewicz, De Swardt & Engelbrecht, 2013), were adapted in order for longer stages to carry more weight. A grade was assigned to every procedural stage. Due to word count limit Figure 1 shows three aspects (procedural stages) of the assessment rubric used to assess students' documentation of the technological process.

	Aspect	Level 4 (Outstanding achieve-ment)	Level 3 (Substantial achieve-ment)	Level 2 (Moderate achievement)	Level 1 (Not achieved)
The technological process					
5	**Initial ideas**	Ideas neatly sketched and captions given, all advantages and disadvantages given, excellent motivation for chosen idea, complete list of problematic aspects. Mark (61-80)	Ideas sketched and captions given, advantages and disadvantages given, relevant motivation for chosen idea, list of problematic aspects given. Mark (41-60)	Ideas sketched are not very clear, few advantages and disadvantages given, motivation for chosen idea not very clear, list of problematic aspects not very clear. Mark (25-40)	Cannot understand sketches, advantages, disadvantages not complete, motivation for chosen idea not complete, list of problematic aspects not complete. Mark (0-24)
6	**Research and develop-ment**	Relevant information will solve problematic aspects with regard to chosen idea. Mark (8-10)	Some information will solve problematic aspects with regard to chosen idea. Mark (6-7)	Vague information to solve problematic aspects with regard to chosen idea. Mark (4-5)	Information not relevant to problematic aspects with regard to chosen idea. Mark (0-3)
7	**Planning (Working drawings, flow chart)**	Flow chart complete and logical, working drawings neat with captions. Mark (48-60)	Flow chart complete and rather logical, working drawings complete with captions. Mark (36-47)	Flow chart complete but vague, parts of working drawings not complete. Mark (19-35)	Flow chart illogical, working drawings not complete. Mark (0-18)

Figure 1: Excerpt of assessment rubric used to assess the technological process

Data gathered from the open-ended questionnaire was analysed through the constant comparative method (Merriam, 1998) and these findings were used to verify the findings from the analysis of the portfolios. By using more than one method of data collection (artefacts and open-ended questions) the researcher ensured trustworthiness of the findings (Creswell, 2005).

Findings

The grades allocated to each procedural stage, for each student, were used to calculate the average per procedural stage and presented as a graph. Although it is quantitative the purpose was only to identify the possible problematic procedural stages. Figure 2 shows the average performance per procedural stage of the technological process achieved by the students' as a group.
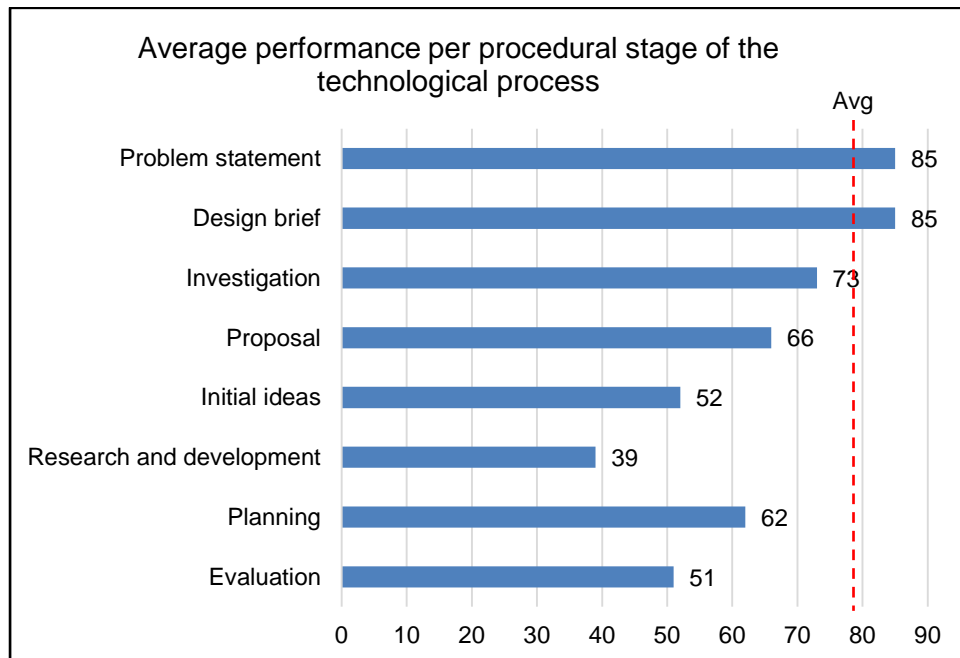
Figure 2: The average performance per procedural stage of the technological process

The average performance of the group for the project in which they were assessed on their interpretation, understanding and application of the technological process was 60%. If the average (60%) is regarded as the benchmark the following interpretations can be made:

Five stages were performed above the average (benchmark): problem statement, design brief; investigation, proposal and planning. Three stages were performed below the average (benchmark): Initial ideas; research and development and evaluation. Although the average for the planning stage is just above the benchmark (62% vs 60%) it can also be interpreted as problematic to some of the students.

By working through the technological process it was required that the students use the thinking process (critical and creative thinking), the decision-making process, the problem-solving process and the design process more than once. Most of the students found it difficult to develop proper initial ideas. Some of the ideas sketched were not clear, advantages and disadvantages given were not all logical and not all students' motivations for their chosen ideas were clear. It was also expected that they list problematic aspects they encountered regarding their ideas, but some of the aspects mentioned were not clear or logical. During the initial idea-generation stage students had to use creative thinking skills when they put their ideas on paper. They had to use critical thinking to analyse the advantages and disadvantages of their different ideas, enabling them to make a value judgement when choosing (decision-making) the best idea. According to Bloom's revised taxonomy (Anderson & Krathwohl, 2001) for the cognitive domain, the thinking dimension applicable to procedural knowledge tends to comprise higher order thinking skills.

Suto and Eccles (2014) also coined the 21st century skills related to the category 'ways of thinking' as higher order thinking skills.

Figure 3 shows examples of students' efforts regarding the idea generation stage. Example A represents a not-so-well presentation. It was expected that the students would make multiview as well as three dimensional sketches with appropriate notes. Example B represents a good presentation.
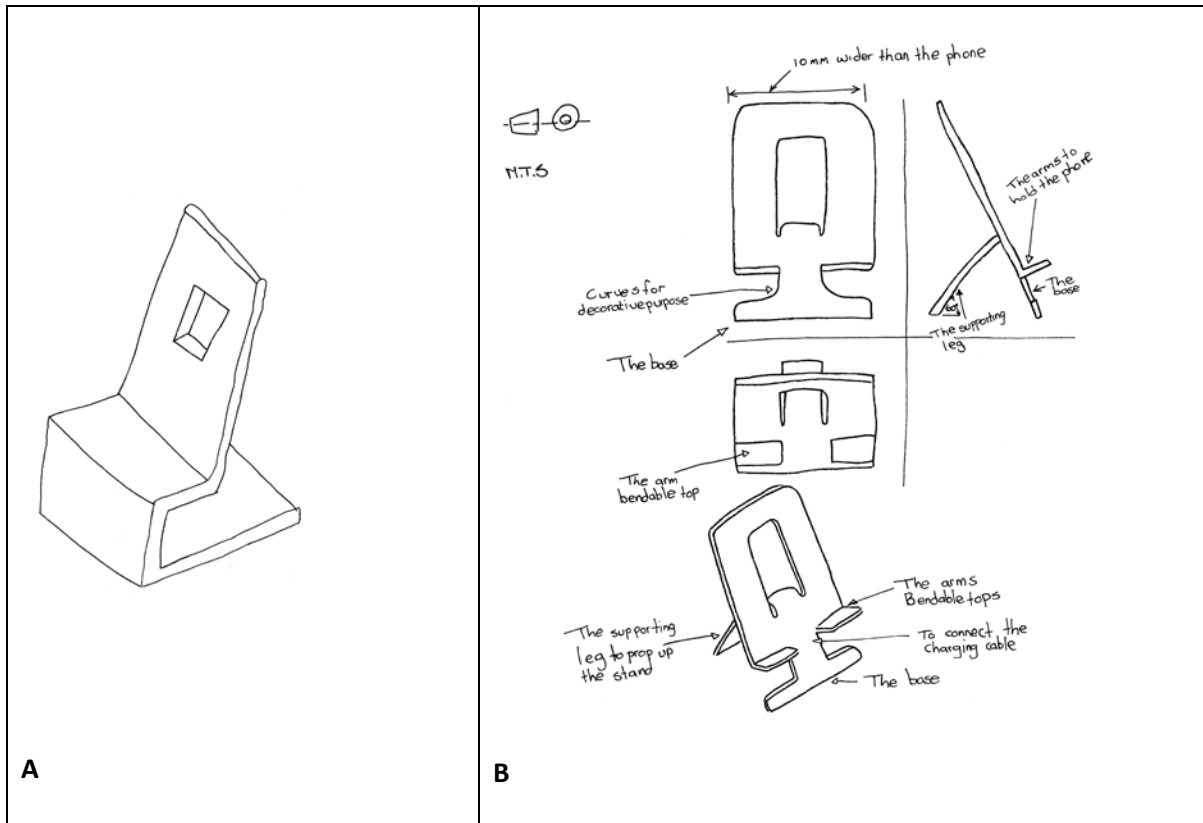
Figure 3: Examples of students' efforts regarding the idea-generation stage

As a group the students achieved their lowest average for the research and development stage. Here they were supposed to research the problematic aspects they encountered regarding their chosen ideas then finalize the development thereof. This was part of the problem-solving process, which included analytical thinking, when they had to make value judgments regarding the development of their final ideas. It also related to the higher order thinking category, analysing on Bloom's revised taxonomy and the 21st century thinking skills, critical thinking, problem-solving and decision-making (Suto & Eccles, 2014).

The planning aspect expected students to generate accurate working drawings, including orthographic projections as well as isometric views of their final chosen ideas. Students' comments/responses in the open-ended questionnaire proved that this procedural stage was problematic for some:

"I struggled to come up with an original idea without making the drawings too   complex for my level of expertise".

"I have also experienced that the more unique your designs are the more   complicated your drawings will be".

From the abovementioned responses it can be argued that the students' drawing competency plays a major role when they had to design products. Drawing competency may restrict students' idea-generation and it may be a prerequisite for more creative ideas.

Figure 4 shows an example of a student's effort regarding the planning stage. The drawing does not include the necessary measurements and a more detailed component drawing should also be included. It is thus clear that the students experienced some difficulty in developing a proper working drawing that would enable somebody to manufacture the object.
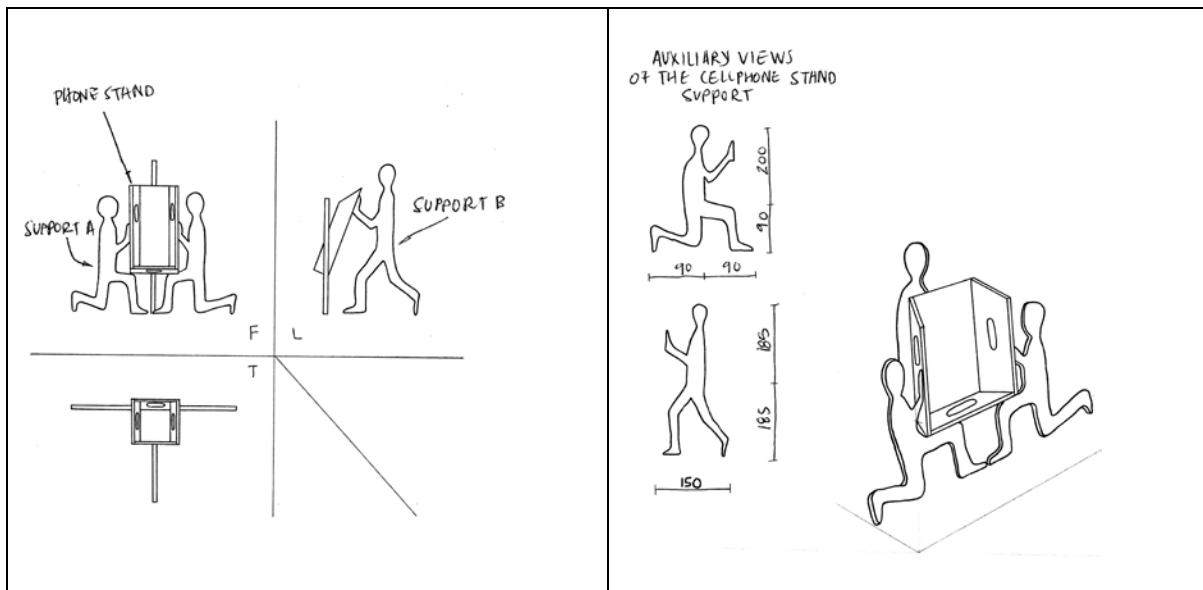
Figure 4: Example of a student's effort regarding the planning stage

Figure 4 shows an example of a student's work that is well grounded with regard to drawing skills.
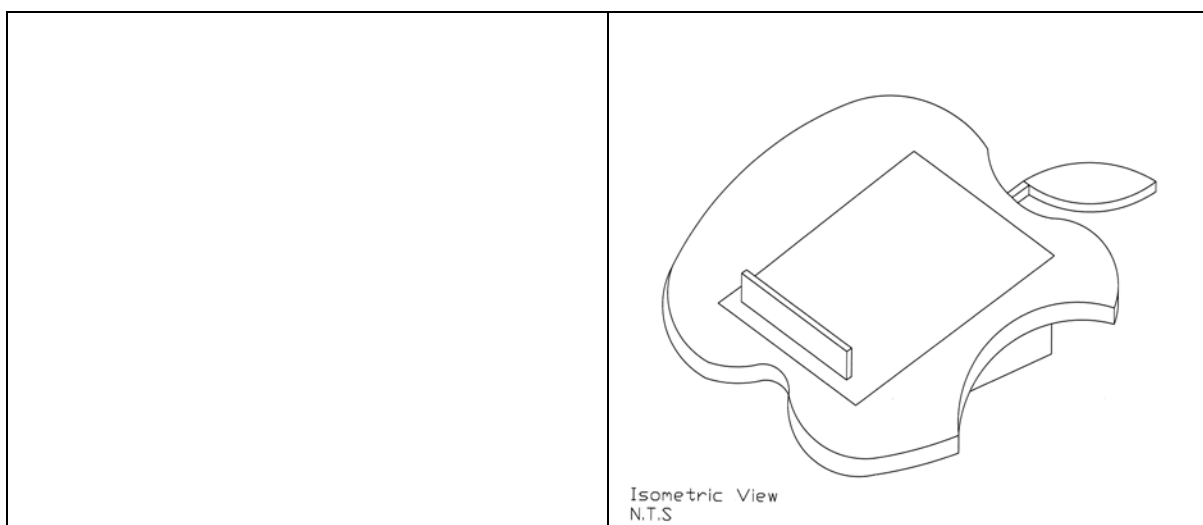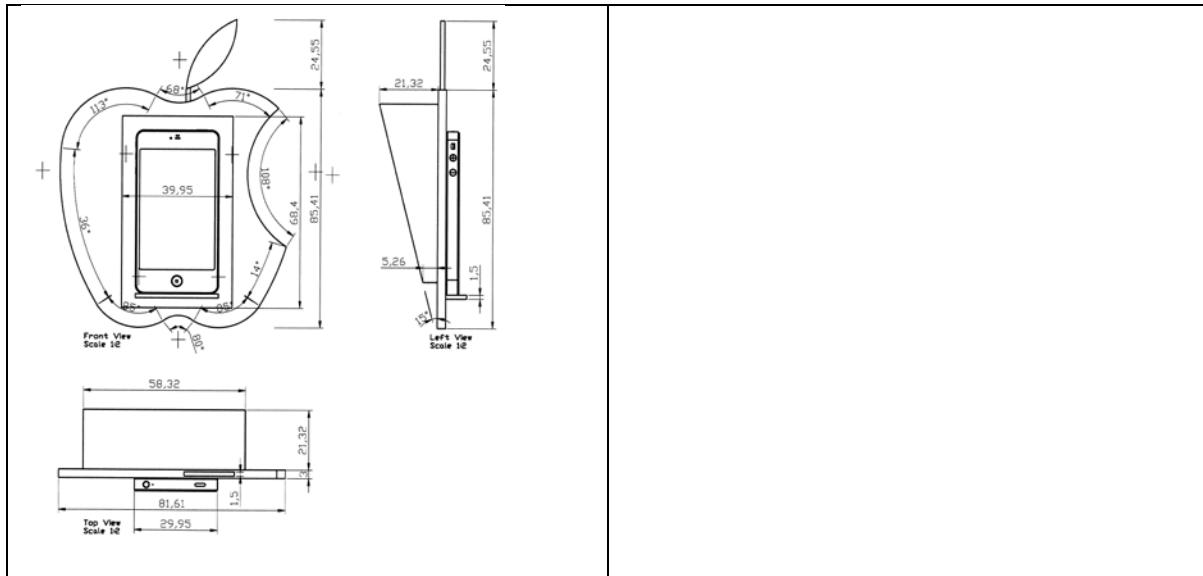
Figure 4: Example of a student's work that are well grounded with regard to drawing skills

Most of the students did not perform well regarding the final procedural stage of the technological process, namely evaluation. They were supposed to use their analytical skills to make a value judgement regarding the suitability of their solutions to the initial problem. Analytical thinking and decision-making proof to be problematic as they encounter difficulty in judging their final designs according to physical properties, construction, function, aesthetics and value. According to Bloom's revised taxonomy, evaluation relates to making judgments based on criteria and standards (Anderson & Krathwohl, 2001).

Students acknowledged that they gained procedural knowledge by applying the technological process when solving a technological problem or need:

"I learned how to creatively design and evaluate a cell phone display stand which was able to carry out its full function".

Discussion

The module EGTE 3B provided students with teaching and learning materials, tasks and experiences which were authentic, real-world and relevant. The module further required students to use and engage with progressively higher-order cognitive processes and provided challenge, interest and motivation to learn.

Students seemingly performed well in five of the procedural stages of the technological process but encountered problems specifically with initial idea generation, research and development and evaluation. Common to these problematic procedural stages was their inability to make value judgments which required critical thinking skills and decision-making. These thinking skills that proved to be problematic to the students also relate to the 21st century skills as part of the category 'ways of thinking', namely critical thinking, problem-solving and decision-making. According to Bloom's revised taxonomy they fall under the higher-order thinking category, namely 'analyse'.

Although the assessment results and the feedback received from the students did show some limitations it can be argued that this project-based module succeeded in improving students' procedural stages satisfactorily as five from nine stages superseded the benchmark of 60%. The module however succeeded, to a lesser extent, to show complex thinking that also relates to 21st century skills.

It is recommended that in future we will have to first emphasize the thinking dimension needed to make value judgements, specifically critical thinking and decision-making before students can apply it to the procedural stages of the technological process.

References

Anderson, L. & Krathwohl, D. A. (2001). Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. New York, Longman.

Ankiewicz, P.J. (2013a). The alignment of the CAPS for technology in the senior phase with the philosophy of technology: a critical analysis. Conference proceedings of the *ISTE International Conference on mathematics, science and technology education: "Towards effective teaching and meaningful learning in mathematics, science and technology",* Mopani camp, Kruger National Park, 21-24 October 2013, 13-25.

Ankiewicz, P. J. (2013b). 'n Teoretiese besinning oor die implikasies van die filosofie van tegnologie vir klaskamerpraktyk. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie,* 32(1), Art.#386, 9 pages. Retrieved from http://dx.doi.org/10.4102/satnt.v32i1.386.

Ankiewicz, P.J. (2015a). 'n Teoretiese besinning oor die implikasies van die filosofie van tegnologie vir kriteria vir vakkurrikulumontwikkeling en -evaluering', *Suid- Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie* 34(1), Art. #1170, 7 pages. http://dx.doi.org/10.4102/satnt.v34i1.1170.

Ankiewicz, P.J. (2015b). The implications of the philosophy of technology for the academic majors of technology student teachers. Proceedings of the PATT 29 Conference, Marseille, France, 7-10 April 2015: pp 13.

Ankiewicz, P.J., De Swardt, A.E., & De Vries, M. (2006). Some implications of the   philosophy of technology for science, technology and society (STS) studies. *International Journal of Technology and Design Education, 16*(2), 117-141.

Ankiewicz, P.J., De Swardt, E., & Engelbrecht, W. (2013). Grade 8 Term 1 Structures, communication skills and mechanical systems and control learner workbook. Johannesburg: University of Johannesburg.

ATC21S (2009). *Assessment and Teaching of 21st Century Skills.* Official website. Available online at: http://atc21s.org (accessed 12 January 2016).

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In Griffin, P., Care, E., & McGaw, B. Assessment and teaching of 21st century skills, Dordrecht, Springer.

Creswell, J.W. (2005). Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research. Upper Saddle River, New Jersey: Pearson.

De Vries, M.J. (2001). The history of industrial research laboratories as a resource for teaching about science-technology relationships. *Research in Science Education, 31*, 15-28.

De Vries, M.J. (2003). The nature of technological knowledge: Extending empirically informed studies into what engineers know. *Techné: Research in Philosophy and Technology*, *6*(3), 1-21.

DoE. (2002). Revised National Curriculum Statement Grades R–9 (Schools): Technology. Pretoria: Department of Education.

Hill, A. M. (1998). 'Problem Solving in Real-life Contexts: Alternatives for Design in Technology Education', *International Journal of Technology and Design Education*, 8(3), 203–220.

Jakovljevic, M., & Ankiewicz, P. (2016). Project-based pedagogy for the facilitation of webpage design. *International Journal of Technology and Design Education*, 26(2): 225-242.

Lombardi, M.M. (2007). Authentic learning for the 21st century: An overview. Educause Learning Initiative. Retrieved from https://www.researchgate.net/profile/Marilyn_Lombardi/publication/220040581_Authentic_Learning_for_the_21st_Century_An_Overview/links/0f317531744eedf4d1000000.pdf

McCormick, R. (1997). Conceptual and Procedural Knowledge, *International Journal of Technology and Design Education*, 7, 141-159.

Merriam, S.B. (1998). Qualitative research and case study applications in education. California: Jossey-Bass.

Rotherham, A.J., & Willingham, D.T. (2010). "21st-Century" Skills. Not new, but a worthy challenge. *American Educator, Spring 2010.* Retrieved from http://www.aft.org/sites/default/files/periodicals/RotherhamWillingham.pdf

Salpeter, J. (2008). 21st Century Skills: Will Our Students Be Prepared? Technology & Learning. Retrieved from http://dca1to1.pbworks.com/f/21st+Century+-+will+our+students+be+prepared.pdf

Snape, P., & Fox-Turnbull, W. (2013). Perspectives of authenticity: implementation in technology education. *International Journal of Technology and Design Education, 23*, 51-68*.*

Suto, I. & Eccles, H. (2014). The Cambridge approach to 21st Century skills: definitions, development and dilemmas for assessment. IAEA Conference, Singapore, 2014.

Turnbull, W. (2002). The place of authenticity in technology in the New Zealand curriculum. *International Journal of Technology and Design Education*, 12(1), 23–40.

Table 1: Curriculum framework for Engineering Graphics and Technology Education

Faculty of Education BEd Senior Phase and FET Teaching				
Name of module	NQF level	Credits	Purpose of the module	Brief description of the content of the module
Engineering Graphics and Technology Education 1A	5	16	The purpose of the module is to introduce students to the fundamentals of technology and graphic communication in order to develop an ability to apply technological knowledge and basic drawing techniques.	Introduction to technology education, Civil technology, Electrical technology and Mechanical technology. Fundamentals of drawing; Freehand drawing techniques; Instrument drawings: Geometrical constructions and scales. Practical application of the basic technological process.
Engineering Graphics and Technology Education 1B	6	16	The purpose of the module is to guide students in developing an understanding of geometrical and orthographic concepts in order to enable multi-view drawing.	Geometric elements; descriptive geometry; solid geometry and the principles of first and third angle orthographic projection.
Engineering Graphics and Technology Education 2A	6	16	The purpose of the module is to guide students in developing knowledge and skills enabling them to apply computer-aided drawing software to present and communicate mechanical artefacts.	Mechanical systems and control; materials for mechanical systems, e.g. metals and plastics; mechanical drawings; isometric drawings.
Engineering Graphics and Technology Education 2B	6	16	The purpose of the module is to guide students in developing knowledge and skills enabling them to apply computer-aided drawing software to present and communicate civil artefacts.	Structures; materials for structures, e.g. steel, timber and concrete; construction methods; civil drawings; perspective drawings.
Engineering Graphics and Technology Education	6	16	The purpose of the module is to guide students in developing knowledge and skills	Electrical systems: Electron theory, Ohm's law, resistance (parallel and series), components,

3A			enabling them to apply computer-aided drawing software to present and communicate electrical artefacts.	diodes, transistors as switches and amplifiers. Basic integrated circuits. Drawing and planning electric and electronic circuits. Interpenetrations. Developments. Loci.
Engineering Graphics and Technology Education 3B	7	16	The purpose of this module is to guide students in developing knowledge and skills enabling them to apply the principles taught to identify and solve complex and diverse design problems.	Application of the technological process: design principles, investigative techniques, data processing techniques, calculations and communication techniques within the contexts of civil and mechanical technologies.

Table 2: Learning guide for EGTE 3B

SEMESTER PROGRAMME

UNIT	THEME		WEEK	ASSESSMENT CRITERIA
1	Design project: Civil Technology	Orientation Project brief	1	Students will be deemed competent if they can: • read the project brief and engage with the technological process.
2		The technological process: • Problem statement • Design brief • Investigation	2	Students will be deemed competent if they can: • identify the problem or need for which they should find a solution; • formulate a design brief by giving a broad indication of what should be designed in order to solve the problem or satisfy the need; • search for information regarding the problem and the possible solution.

3		The technological process (continued): • Proposal • Initial ideas	3	Students will be deemed competent if they can: • formulate a proposal regarding a tentative solution. The proposal should include specifications and a time frame indicating how long it would take to complete the project; • develop ideas in the form of freehand sketches. The different ideas should be weighed up in terms of their advantages and disadvantages by means of critical analysis. • select one idea to be developed further.
4		The technological process (continued): • Research • Developing the chosen idea • Planning	4	Students will be deemed competent if they can: • research problematic aspects regarding the chosen idea; • resolve all the problematic aspects regarding the chosen idea; • generate working drawings by using CAD; • compile a list of materials for the actual product.
5		The technological process (continued): • Making	5	Students will be deemed competent if they can: • identify appropriate material and make a model according to the working drawing; • demonstrate safe conduct and use of tools in the workshop.
6		The technological process (continued): • Making (continued) • Evaluate and improve	6	Students will be deemed competent if they can: • complete the model according to the working drawing; • demonstrate safe conduct and use of tools in the workshop; • evaluate the final product against pre-set criteria and improve it if necessary.

Exploring STEM education in the context of learning about sound, waves and communication systems: students' achievements and

Nayif Awad[1, 2], Moshe Barak[1]
[1]Ben-Gurion University of the Negev, Israel
[2]Sakhnin College – Academic College for Teacher Education, Israel
Department of Science and Technology Education,
Ben-Gurion University of the Negev, Beer Sheva, Israel
awad_nayif@yahoo.com
mbarak@bgu.ac.il

motivation

Abstract

This work presents the case of the development, implementation and evaluation of a STEM-oriented course on a sound, waves and communication systems in middle school. The program adopted four principles: contextual learning, interdisciplinary learning, ICT-based learning and project-based learning. Students' activities included hands-on lab work, the use of simulations and software for sound analysis, and preparing final projects. The research aimed at exploring the factors affecting students' success and motivation in learning an advanced scientific-technological subject. Quantitative and qualitative data were collected, for example, by exams, an attitude questionnaire and interviews. The students successfully learned the new subject, and their self-efficacy about learning science increased due to the flexible integration of teachers' instruction, hands-on lab work, the use of ICT and project-based learning.

Keywords: STEM, Sound, Waves, Communication, ICT, Projects

INTRODUCTION

More and more educators are coming to realize that science education is still facing great challenges. First, the common science curriculum is disconnected from the student's world and daily life (Bouillion, and Gomez, 2001). Second, the school curriculum is taught as separate subjects such as physics, biology, chemistry, mathematics and technology, without any interaction between these areas, as is found in real life. Third, the powerful potential of using modern information and computer technologies (ICT) for teaching and learning science and developing teachers' and students' digital literacy is only little realized in school (Osman and Vebrianto, 2013; Van, 2011). Fourth, the traditional 'talk and chalk' teaching method is still dominant in school, while the educational literature widely recommends a shift towards student-centered instruction methods such as inquiry and project-based learning (PBL) (Granger et al., 2012). To address these challenges, we developed a STEM (science, technology, engineering and mathematics) program for teaching a Sound, Waves and Communication systems (SWC) course in a rich ICT-based environment, which is the subject of this paper. In the following section, we present the theoretical background for this study, the course outline, and the findings from the evaluation of students' learning and motivation along the course. The main questions that guided this study were: 1) To what extent can junior high school students learn an advanced scientific-technological subject such as a sound, waves and communication system?; 2) What factors contribute to or hinder their success in learning the subject?

LITERATURE REVIEW

The research presented in this paper is innovative in that it brings together four concepts derived from the contemporary literature on teaching and learning: contextual learning, interdisciplinary learning, project-based learning and ICT-based learning, as illustrated in Figure 1.
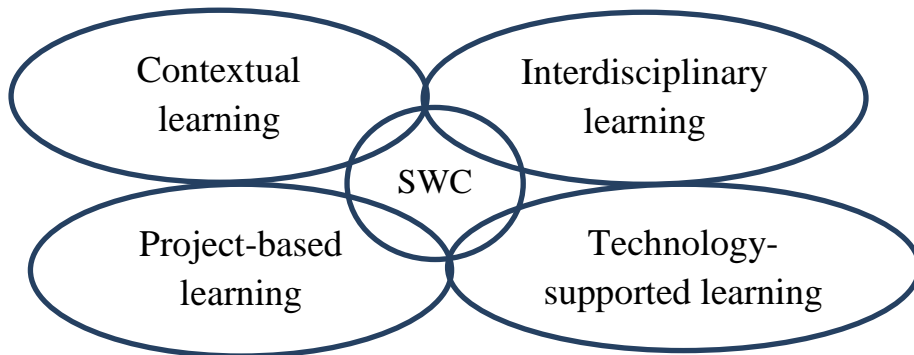
Figure 1: The conceptual framework of the Sound, Waves and Communication systems (SWC) course

Contextual learning

Contextual learning is a reality-based learning that provides students with opportunities to make meaning of their learning and solve problems within a real-world context (Fosnot, 1996; Greeno, Collims & Resnick, 1996). In the course under discussion, the students learn about the nature of sound, the structure and function of an electronic sound amplification system, and digital sound. All these subjects relate very closely to young children's lives.

Interdisciplinary learning

Recently, the term STEM – science, technology, engineering and mathematics – has caught the attention of educational researchers and policy-makers as a framework for fostering scientific literacy learning in schools, for example: the discussion about STEM education in the United States (Brown et al., 2011; the Science, Technology, Engineering and Mathematics (STEM) Program Report in England (DFES and DTE), 2006; the Australian Council of State School Organizations (ACSSO) Digits ,2010; and the OECD Workshop Summary, 2011). According to Bybee (2010), "STEM literacy includes the conceptual understandings and procedural skills and abilities for individuals to address STEM-related personal, social and global issues." The current research included the development and evaluation of a curriculum for integrative learning science, technology engineering and mathematics aspects of sound and communication systems.

Technology-supported learning

The rapid spread of information and computer technologies (ICT) in education has given rise to hopes that new technologies would largely influence education. Skryabin et al. (2015) investigated how the national ICT development level and individual ICT usage will influence achievements in reading, mathematics and science for 4th- and 8th-grade students. Analysis of large-scale international databases, including TIMSS 2011, PIRLS 2011 and PISA 2012, showed that the national ICT development level is a significant positive predictor for individual academic performance in all three subjects for both 4th-and 8th-grade students, while the national economic development level was controlled.

Rogers and Twidle (2013) point out that the most significant products of teachers' professional development are the integration of ICT in the curriculum and a change in a teacher's pedagogy towards teaching approaches that empower students to work more independently and

reflectively. In the current study, the use of ICT lies at the heart of teaching and learning science, for example, using interactive scientific simulation for lab experiments in physics and electronics, or sound analysis software. In the current research, evaluation concentrated on how teachers and students use ICT, and the effects of using ICT in the cognitive and affective domains.

Project-based learning

Project-based learning (PBL) is undoubtedly one of the best teaching methods for developing students' broad learning capabilities, beyond teaching specific subject matter (Blumenfeld et al., 1991; Capraro et al., 2013). PBL encourages students to be active learners by engaging them in reality-based problems that resemble situations they might encounter in their lives and provides them with opportunities to make meaning of their disciplinary knowledge. The process can bring more freedom to students in their learning regarding the way they prefer to learn, setting the pace of learning, choosing the contents, and inviting more opportunities for the self-learning experience and independent decision-making. In the current research, the students worked on a small project during the last phases of the course.

METHOD

Research approach

This study is an *evaluation research*, which is a form of applied research that scrutinizes how well a particular program, practice, procedure or policy is operating (Tavakol, Gruppen, and Torabi, 2010). The evaluation referred to an innovative program for learning about sound waves and communication systems that was developed by experts in science and technology education and was tried out in several schools. As Powell (2006) writes, evaluation research often employs standard research methods for evaluative purposes, for example, qualitative and quantitative research methods; the differences between evaluation research and other types of research center on the orientation of the research and not on the methods employed.

The Sound Waves and Communication systems (SWC) course

The course is designed for 15 successive weekly sessions of 90 minutes each (two classroom hours). It aims at providing junior high-school students with: 1) scientific concepts, such as transitive wave, longitude wave, period (T), frequency (f), wavelength (λ), amplitude (A), sound velocity (v), and sound propagation on different materials or states of matter; and 2) technological concepts, such as sound system, microphone, speaker, amplifier, amplification process, analog to digital conversion process, digital sound.

The teaching method adopted the TLIP model, combining four teaching-learning modes: **T**eacher's short presentations (for example, 15 minutes); hands-on **l**ab work (for example, 25 minutes); **I**CT-based learning (for example, 25 minutes), such as using scientific simulations in physics and electronics or software for sound recording and analysis; and **p**roject-based learning (for example, 25 minutes), in which the students prepare small projects and present their work in the class. It should be noted that the time periods mentioned above are just examples, because the mode and length of students' and teachers' activities varied from subject to subject or from class to class depending on the subject learned and the students' responses. Figure 2 illustrates two examples from the students' work in the class.

Testing a magnetic microphone using the Audacity software

Constructing a tweet dell (electronics kit)

Figure 2: Examples from students' activities in the class

Setting

The participants comprised six separate groups of 10-20 students each, for a total of 80 students (7th grades, ages 13-14) from five junior high schools in northern Israel. The study took place either in school or in a regional educational center. The classes were heterogeneous, comprised of regular students in their schools.

Quantitative data collection tools

- *Midterm exam* comprised of 13 multiple-choice questions about sound waves. Most of the test items were taken from a student-centered tool that was suggested by Eshach (2014) in order to assess middle school students' conceptual understanding of sound.
- *Final comprehensive exam* about the main subjects students learned in the course: waves (in general), analog sound waves, electrical amplification systems and digital sound. It contained five questions divided into total of 18 items, about **factual knowledge (six items), procedural knowledge (six items) and conceptual knowledge** (six items). To ensure the validity of the exam, a panel of experts classified each sub-question according to its suitable knowledge type.
- *Students' attitudes questionnaire*: a close-ended Likert-type attitudes questionnaire was administrated in the classes pre and post the course to examine students' attitudes towards learning STEM. The questionnaire comprised of 12 items spread over three categories: motivation and interest in learning science and technology; desire to learn in ICT based environment; and self-efficacy beliefs about learning new topics. The questionnaire was revised in several rounds according to experts' panel comments and suggestions.

Qualitative data collection tools

- *Class observations* – documenting students' activities in the class.
- *Students' reflection questionnaire* – an open-ended reflection questionnaire distributed twice to all students in the course in the fifth and the tenth sessions.
- *Final projects* – an analysis of final projects the students prepared using a scale (indicator) that was developed by another community of science and technology teachers in middle schools. The scale comprised of four categories: content, structure, graphic design and oral presentation.
- *Students' interviews* – 35 interviews conducted with groups of 2-3 students at the end of the lessons. Each interview lasted about 10-20 minutes, and the researcher asked different questions related to the learning in the course such as: *"Explain to me how sound propagates in air?"*, *"What's the difference between the learning in this course and learning at school?"*

FINDINGS

Since the limited scope of this paper, we will present briefly the study's findings based on qualitative and quantitative data. Because of ethical reasons we didn't employ a control group that was taught similar content through more conventional approaches.

Outcomes of the midterm exam

The exam included 13 multiple-choice questions about the nature of sound waves, and sound propagation in air and other materials. Most of the questions were taken from Eshach's (2014) work on students' understandings of sound and were reviewed by two experienced physics teachers. For example, one of the questions was:

When you stand behind the door to a room in which music is playing, you can still hear the music because:

    a. The sound is made of small particles that can pass through gaps, like the one between the door and the floor.

    b. The changes in air density formed in the gap between the door and the floor travel outside.

    c. The sounds in the room cause the wall to vibrate. The vibrating wall causes the air on the other side to vibrate and slightly changes the air pressure there. (the correct answer)

The mean score in the class was 69.00 on the scale 0-100 (n=70, SD=19.27). This finding reflects the fact that despite the rich class activities, several weeks was not enough time for the students to develop conceptual understanding.

Outcomes of the final exam

The final exam comprised five questions (each question divided into 3-4 sub-questions) in three categories:

Factual knowledge (six items) (35%), for example: What is the sound velocity in air? (Answer: 344 m/sec)

Procedural knowledge (six items) (32.5%), for example: Given the time period T=0.01 sec and the wavelength λ=20 cm of a wave, find a) the velocity of the wave, b) the distance the wave propagates in 1 second. (Answers: 20 m/s; 20 m).

Conceptual knowledge (six items) (32.5%), for example: a) Which two of graphs A, B, C, D (Figure 3) can describe a loud sound (relative to low intensity sound); b) Which two of graphs A, B, C, D can describe a violin's tone (relative to a drums' tone)? (Answers: A, B; B, C).
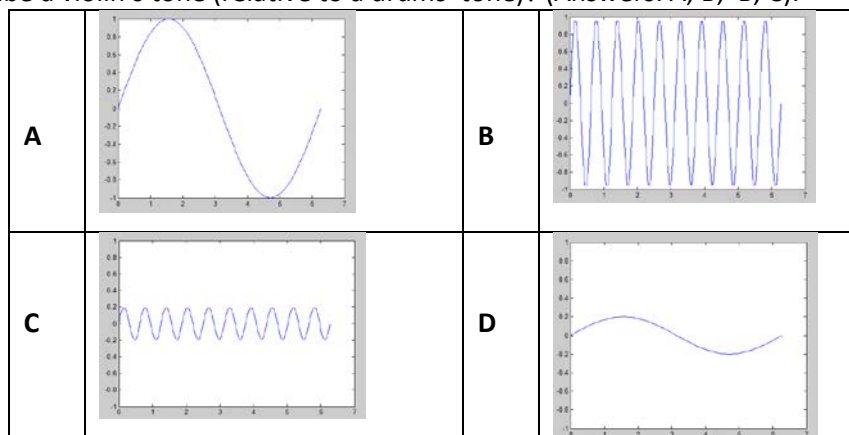
Figure 3: Example of conceptual questions from the final exam.

The average scores (on the scale 0-100) in the final exam (n=72) were 80.02 in the factual knowledge questions (SD=13.93), 85.87 in the procedural knowledge questions (SD=17.30) and 80.15 in the conceptual knowledge questions (SD=14.50).

The relatively high scores in the procedural knowledge questions reflect the fact that science and technology teachers often emphasize learning procedural knowledge, for example, solving problems using mathematical formulas. The relatively good achievements in the conceptual

knowledge questions indicate that the students acquired significant scientific-technological knowledge about the topics studied in the course.

To compare students' achievements in the final exam versus the mid-term exam, a paired t-test of the difference between mean scores in the two exams was conducted. The findings indicate that the final exam scores (n=72; Mean=80.77.00; SD=11.79) were significantly higher than the mid-term exam scores (n=70; Mean= 69.00; SD=19.27) (t=3.03; sig<0.005). The improvement in students' achievements could be attributed to the experience and confidence they had gained in the course, as was found from the observations held in the class and the interviews with the students.

Outcomes from the students' final projects

Students chose topics that interested them from the field of sound waves and communication systems, for example digital music and home sound system. They studied the subjects independently and prepared theoretical presentations. The findings show that only 31% of the students managed to fulfill the content requirements of the project- relevance, accuracy and richness of information. In contrast, more than half of the students completed the structure and graphic design requirements. The students' best performance was in the oral presentation, something that should not be taken for granted considering the students' young age.

Findings from the attitude questionnaire the students filled in pre and post the course

As already noted, the questionnaire comprised of 12 Likert-type items in three categories:

1. Motivation and interest in learning science and technology (4 items).

For example, "*I am interested in studying science subjects.*"

2. Desire to learn in an ICT-based environment (4 items).

For example, "*I look for information on the Internet in my free time.*"

3. Self-efficacy beliefs about learning new science topics (4 items).

For example, "*I can study alone and learn more about science.*"

The students marked their answers on the scale of 1 – strongly disagree, 2 – disagree, 3 – agree, 4 – strongly agree. The Cronbach's Alfa reliability coefficient for the three categories mentioned above for the pre-course data was 0.580, 0.236, 0.774, respectively, and 0.562, 0.599, 0.835 for the post-course data, respectively. The findings from students' answers and the paired-sampled t-test to compare mean scores between pre and post course answers are presented in Table 1.

Category	Pre-course Mean	SD	Post-course Mean	SD	t-test	Sig
Motivation to learn science and technology	3.6971	.42685	3.6394	.38797	.0017	0.319
Desire to learn in an ICT-based environment	3.1538	.46746	3.1635	.55325	0.118	0.907
Self-efficacy beliefs about learning new science topics	2.6202	.76134	2.9279	.68838	2.889	0.006*

Table 1: Findings from the attitude questionnaire about learning science and technology the students answered pre- and post the course *(*p<0.05)*

The findings in Table 1 show that students' motivation to learn science and use ICT were high both at the beginning and the end of the course, with no significant difference. However, learners' self-efficacy beliefs about learning science were relatively low before the course and increased significantly at the post-course measure. This is perhaps one of the most important outcomes from the current study.

54

Findings from observations and interviews

About 90% of the students who began the SWCS course completed it, i.e., they attended at least 12 out of 15 sessions. Many students who were forced to be absent informed their teachers in advance. To examine the reasons for the students' high commitment and motivation, the researcher asked them in interviews: "*To what extent does the course interest you (high extent/medium extent /low extent)? Why*?" The qualitative data analysis showed that most of the students answered "high extent." The students expressed their satisfaction in dealing with different subjects at the same time. They also declared that the teacher used different methods for teaching them the course contents, which helped them overcome difficulties and made the class sessions more enjoyable. Below are examples of students' statements during the interviews:

- "*We learned new ideas in more than one method... The same idea was repeated in the class discussion, during the experiment and while solving a computerized activity.*"
- "*I liked learning everything together... physics, electronics, computer and mathematics.*"
- "*I wasn't completely bored during the lesson because it contained many things, like hands-on work and computer use.*"

Conclusions

The findings show that junior high school students are capable of learning and understanding basic scientific-technological concepts related to sound, waves and communication systems at the level of basic physical explanations and simple mathematical calculations. The findings reinforce the most important factors that contributed to the learners' success and motivation in the current course. These were: (a) engaging the students in a variety of knowledge types and activities in a rich learning environment, and (b) the flexible integration of teachers' instruction, hands-on lab work, the use of new media technologies, and project-based learning. The combination of these instructional methods was chosen considering that young children need preparation and guidance before being able to deal with challenging tasks and independent learning.

References

Australian Council of State School Organizations (ACSSO), (2010). *Australian Education Digest, STEM Education Special*. Available at http://www.acsso.org.au/AED100923.pdf (accessed 10.7.2012)

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: sustaining the doing, supporting the learning. *Educational Psychologist, 26*, 369-398.

Bouillion, L. M., & Gomez, L. M. (2001). Connecting School and Community with Science Learning: Real World Problems and School-Community Partnerships as Contextual Scaffolds. *Journal of Research in Science Teaching*, 38, 8, 878-98.

Brown, R., Brown, J., Reardon, K., & Merril, C. (2011). Understanding STEM: Current Perceptions. *Technology and Engineering Teacher*, *70*(6), 5-9,

Bybee, R. W. (2010). Advancing STEM education: a 2020 vision, *Technology and Engineering Teacher, 70*(1), 30-35.

Capraro, R. M., Capraro, M. M., & Morgan, J. R. (2013). STEM project-based learning: an integrated science, technology, engineering, and mathematics (STEM) approach. Rotterdam: Sense Publishers.

Creswell, J. W., & Plano, C. V. L. (2007). *Designing and conducting mixed methods research.* Thousand Oaks, California: SAGE Publications.

Department for Education and Skills (DFES) and Department for Trade and Industry (DTE) (2006). *The Science, Technology, Engineering and Mathematics (STEM) Programme Report*. Department for Education and Skills, London.

Eshach, H. (2014). Development of a student-cantered instrument to assess middle school students' conceptual understanding of sound. *Physical Review Special Topics - Physics Education Research, 10(1)*, 010102.

Fosnot, C. T. (1996). *Constructivism: Theory, perspectives, and practice*. New York: Teachers College Press.

Granger, E. M., Bevis, T. H., Saka, Y., Southerland, S. A., Sampson, V., & Tate, R. L. (2012). The efficacy of student-centered instruction in supporting science learning. *Science*, 338(6103), 105-108.

Greeno, J. G., Collims A. M. & Resnick, L. B. (1996). Cognition and learning. In Berliner, D. C. and Calfee, R. C. (Eds.) *Handbook of Educational Psychology* (pp. 15-46). New York: MacMillan.

Organization for Economic Co-operation and Development (OECD) (2011). *Education for Innovation*: *The Role of Arts and STEM Education*, Workshop Summary Report. Available at http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=EDU/CERI/CD(2011)8anddocLanguage=En (accessed 10.7.2012)

Osman, K., & Vebrianto, R. (2013). Fostering science process skills and improving achievement through the use of multiple media*. Journal of Baltic Science Education*, *12*(2), 191-204.

Powell, R. R. (2006). Evaluation Research: An Overview. *Library Trends, 55*(1), 102-120.

Rogers, L., & Twidle, J. (2013). A pedagogical framework for developing innovative science teachers with ICT. *Research in Science & Technological Education*, *31*(3), 227-251.

Skryabin, M., Zhang, J., Liu, L., & Zhang, D. (2015). How the ICT development level and usage influence student achievement in reading, mathematics, and science. *Computers & Education*, 8549-8558.

Tavakol, M., Gruppen, L. D., & Torabi, S. (2010). Using evaluation research to improve medical education. *The Clinical Teacher, 7*(3), 192-196.

Wan, N. (2011). Why digital literacy is important for science teaching and learning. Teaching Science: *The Journal of the Australian Science Teachers Association*, 57(4), 26-32.

Preschoolers' Conceptions of Technological Artefacts and Gender in Picture Books

Cecilia Axell
Linköping University
Department of Social and Welfare Studies
Norrköping
Sweden
cecilia.axell@liu.se

Johan Boström
Linnaeus University
Department of Physics and Electrical Engineering
Växjö
Sweden
johan.bostrom@lnu.se

Abstract

Picture books are a frequent element of daily preschool activities (Damber, Nilsson & Ohlsson, 2013; Simonsson, 2004; SOU 2006:75). They are important pedagogical tools that can help children acquire an understanding of the everyday technology they come in contact with, as well as the human application of technology (Axell, 2015; Axell & Boström, 2015). These are skills that are emphasised in the Swedish preschool curriculum. In the curriculum it is also stated that the preschool should counteract traditional gender patterns and gender roles (Skolverket, 2010). However, an investigation of a selection of picture books aimed at preschool children shows that the books content is somewhat problematic. Many of the picture books provide a focus on the function of separate artefacts without any sort of context or explanation of their implications in a societal context. There also tends to be an emphasis on traditional masculine-coded technology in the books. Building and making and working with machines is depicted as a male activity. The male stereotype is essentially connected with different kinds of vehicles like cars, airplanes, motorbikes, tractors etc. (Axell & Boström, 2015; See also Holbrok, 2008). Based on these previous findings, the aim of this pilot study was to obtain an initial concept about how children's literature may influence preschool children's view on technological artefacts. The study was conducted through semi-structured interviews with four five-year-olds, two girls and two boys. Through a thematic analysis (Braun & Clarke, 2006) three overarching themes were identified: *The relationship between design and function, anthropomorphic animals as users of artefacts*, and *gender and artefacts*. Some of the key findings were that the 5-year-olds did not know what "technology" is, but had good knowledge about tools. Additionally, they did not genderise any of the artefacts included in the study.

Keywords: Technology education, preschool, picture books, gender, Sweden

Introduction

This paper is part of a larger study regarding technology in children's literature from a gender perspective. The first part of the study was reported at the PATT 29 conference (see Axell & Boström, 2015). One of the main results from the initial study was that technology in children's literature is often presented from an artefact perspective. Another result was that there is a heavy focus on masculine coded technology in books aimed for children. Men are presented as

both designers and users of technology. Men and women are also, more often than not, presented in a stereotypical manner. Our conclusion was that while children's literature may serve as an introduction to everyday application of technology, it also runs the risk of conserving stereotypical gender patterns. The research presented in this paper is a pilot study and our first step in shedding some light on how children's literature may influence preschool children's view on gender regarding to technological artefacts.

It should come as no surprise that technology and its various accompanying fields is a gendered arena. Society's view of gender and technology is always shaped in mutual processes (Berner, 1999; 2003; Faulkner, 2003) or as Nissen (2003) puts it: "[technology] is an inseparable part of a social and cultural context" (our translation, p. 89). The cultural image of technology belonging to a masculine sphere can be traced at least 500 years back in the history of western culture. This symbolism between masculinity and technology was then enhanced even more during the turn of the last century and the rise of the engineer as a male role model (Berner, 1999). This hero-worship of the technology savvy man has ever since taken root in our collective consciousness. Just look at inventors and scientists in popular culture, these are almost exclusively male (Nyberg, 2003). Dr. Frankenstein, Reed Richards (from the Fantastic Four), Tony Stark, Gyro Gearloose, Professor Cuthbert Calculus just to name a few.

According to Faulkner (2003) the connection between gender and technology can be categorised from a couple of different perspectives, one of them being cultural images. This symbolic connection between masculinity and technology also mediates a dichotomous hierarchical notion of a "male", "hard" technology and a "female", "soft" technology (Berner, 2003). This notion becomes even more apparent when looking at particular kinds of masculinity, what Mellström (2003) categorises as "the handy man", "the engineer" and "the hacker". The picture mediated by these cultures is often that of the technology savvy, hands-on-no-question-asked male, while simultaneously presenting the image of the technologically incompetent woman. Another connection between gender and technology has to do with the genderisation of artefacts – symbolical and/or material. The symbolic genderisation means that certain artefacts may not be designed with a female or male user in mind but have fallen into one of these categories through common everyday use. It also has to do with the societal discourse of naming artefacts or parts of artefacts as "he" or "she". The material genderisation concerns the aspect of the design of the artefact being able to create and/or enhance gender differences (Faulkner, 2001; 2003; Sorensen & Berg, 1987).

Research has shown that children's literature has the capacity to influence preschool children's view of their understanding of the world and themselves. One perspective of this understanding has to do with the children's understanding of gender – of society's femininity and masculinity norms (Crisp & Hiller, 2011; Gooden & Gooden, 2001; Hellsing, 1999; Kåreland, 2013; Reynolds, 2011; Trepanier-Street & Romatovski, 1999). However, it has been documented that these books often have presented a stereotypical view on gender (Axell & Boström, 2015; Hamilton et al., 2006; Martin & Siry, 2009). The fear has been that these books will socialise children into traditional roles and limit their interest in other activities that may also suit them (Gooden & Gooden, 2001; Oskamp et al., 1996).

It has also been documented that many picture books use anthropomorphic animal characters to highlight human intentions, knowledge and different abilities. Anthropomorphic animals are for example able to build houses, drive cars and so on (Ganea et al., 2014). However, there is research, (e.g., Ganea, et al 2014; Legare et al 2013) that proposes that books using anthropomorphic animals as main characters may hinder the children in connecting the information conveyed to the real world.

Purpose of the Pilot Study

Taking previous research as our outset and putting it in relation to the findings of the first part of our study, the aim of this pilot study was to investigate how children view and relate to technological artefacts presented in picture books. More precisely; we wanted to examine how children view the characters and artefacts presented in these books. *In what way do anthropomorphic stories have an impact on preschoolers' view of technological artefacts and their function, in relation to gender*?

Methodology

Participants

The pilot study took place at a preschool in a city of Sweden. Four children, two girls and two boys, were interviewed by one of us while the other one took field notes. The interviews were semi-structured. The children were interviewed in pairs (a boy and a girl) and each interview took approximately 20 to 30 minutes. The interviews were also video recorded and have subsequently been transcribed into verbal text.

Presentation of the Books

In the first part of the larger study 180 picture books were used as the subject for analysis. Two of these books were singled out for the part presented in this paper – *Castor Does Carpentry* and *Mamma Moo Builds a Tree House.* The selection was based on the notion that we wanted two books, both of which focused on main characters dealing with different kind of tools. A second criterion was that one of the books would have a female main character and the other a male. We chose not to read the books to the children, partly because we did not want to influence their interpretation of the illustrations and partly because most preschoolers "read" through the illustrations when on their own (e.g., Elster, 1995; Simonsson, 2004).

Castor Does Carpentry is about Castor, a male beaver. He lives alone in a house and spends most of his days hanging with his friend Frippe, who also is a male beaver. Together they are making stuff. In *Castor Does Carpentry* their aim is to build a tool kit for all of Castor's tools. During the course of the book the different tools and how to use them are thoroughly described. In the book the only characters present are Castor and Frippe.

Mamma Moo Builds a Tree House revolves around the main character of Mamma Moo, who is a female cow, and her best friend Crow, who is a male crow. Mamma Moo lives on a farm but she sometimes strays from the farm to visit her friend Crow in the nearby forest. In *Mamma Moo Builds a Tree House* she does precisely that and happens to see some children building a tree-house. She instantly wants to build her own and goes to Crow to tell him about her idea. During the course of the book we see how both Mamma Moo and Crow use different tools to build their respective tree-houses.

Design and Procedure

Earlier research has shown that children talk more about artefacts when they are presented in a three-dimensional way (Evangelou et al., 2010). The problem regarding this way of presenting the artefacts is the lack of context, something a picture book can provide. When technology is not placed in a broader context, the connections between artefacts and humans are disregarded (Klasander, 2010; Mawson, 2007; Siu & Lam, 2005; Svensson, 2011). Taking this into account the

following real world artefacts appearing in the books were brought along to the interviews by the researchers – *a hammer, a pen, a handsaw, a brace drill* and a *folding ruler*. Because all of these artefacts can be seen as masculine coded technology belonging to the sphere of the "handy man" (Mellström, 1999), some other artefacts were also brought along – a *cell phone, a heat gun, a woollen cap, a whisk* and *a hair straightener.*

We first asked the children what they knew about technology and what technology meant for them. The children were then introduced to Mamma Moo and Castor in the form of laminated pictures of the characters. These pictures were then positioned at opposite ends of a string, with a clip marking the middle of the string.

The children were then asked who they thought used the different artefacts. If the children answered that an artefact was used solely by Mamma Moo it was placed at that end of the string, if the children said that it was used equally by the two characters it was placed in the middle (i.e. the clip) and so on.

Analysis and Discussion

The material was analysed using a thematic analysis (Braun & Clarke, 2006), which ultimately resulted in three different themes: *The relationship between design and function, anthropomorphic animals as users of artefacts*, and *gender and artefacts*.

The Relationship between Design and Function

All four children had good knowledge about most of the artefacts. Initially, the children seemed to identify the artefacts function from the design. For example they named the folding ruler a "measurer" and the brace drill, hardly a tool that most children come in contact with today, was named "drillerer". The only artefact they could not identify was the heat gun, which they thought was a glue gun. A glue gun is a common artefact in Swedish preschools and the two guns have a lot in common regarding their surface design.

This is in line with Gelman & Blooms (2000) suggestion that an important aspect for children when naming artefacts has to do with their view of the intent of the creator. Matan & Carey (2001) showed that, while perhaps not fully understanding the design stance (i.e. that an artefact is created to fulfil an intended function, and that this function is the artefacts essence) 6-year olds understand artefacts in terms of function and relate this to human action in the form of what the artefacts originally were made for. However, they found that 4-year olds where prone to not take the intent of the designer into consideration and instead relying on current, contextual use of the artefact. Kelemen (1999) on the other hand showed that when 4-year olds were asked what an object was for, they tended to ignore the object's ultimate use in favour of what it was originally intended for.

Later in the interview, all four children used correct labels for the tools. This can be interpreted in relation to the dual nature of physical artefacts. They are both physical objects of a certain size, shape, colour, weight, etc., but also have a certain functional dimension (de Vries, 2006).

That the children could positively label an artefact they had never come in contact with before (the brace drill) may be explained in that the design of the artefact met two of Normans (2002) characteristics of good design *discoverability* and *understanding*. The discoverability is about the possibility to figure out what actions are possible and how to perform them. Understanding is related to how the product is supposed to be used. This could of course also be indicative of earlier research that demonstrates that children who get in contact with technological artefacts in

their leisure time, also have good knowledge about them (Mawson, 2010; 2011; Milne & Edwards, 2011; Outterside, 1993; Roden; 1995). Mawson (2010), for example, found that it was more common with technology activities together with a male relative than a female. Mawson's study also showed that men who worked in crafts seemed to have a greater influence on whether children came into contact with technology activities or not. This is something that we could investigate further in the forthcoming study.

Anthropomorphic Animals as Users of Artefacts

We have not found any prior studies that examine how anthropomorphic animals affect children's understanding of the use of technology, but there are studies that explore how anthropomorphic animals in children's books affect children's conceptions of real animals (e.g., Ganea, et al., 2014). The fact that there were anthropomorphic animals handling tools in our pilot study did not seem to affect the children's understanding of what the tools were or their function.

All of the children seemed to have prior knowledge about *Mamma Moo* as a character, for example they talked about films starring her, and they also referred to a poster of Mamma Moo on a wall at the preschool. None of the children did however recognise Castor.

This prior knowledge or non-knowledge about the characters seemed to influence the first pair heavily when deciding where on the string to put the different artefacts. They ended up giving most of the artefacts to Mamma Moo except the woollen cap, which they gave to both characters, and the pen and the heat gun, which they gave to Castor. However, when they were introduced to *Castor is Doing Carpentry* they quickly rearranged the artefacts in his favour. Subsequently, when introduced to *Mamma Moo Builds a Tree House,* the children rearranged them in both of the characters favour.

Child 2: Does she use a drill to…yeah, I see on that (*points at the cover*), so… the hammer (*picks up the hammer and positions it at Mamma Moo's end).*
Researcher: The hammer. Does Mamma Moo have the hammer?
Child 1: No, both of them use it (*positions it in the middle*).

The other pair were, however, more influenced by Castor having human looking hands and that Mamma Moo does not when distributing the artefacts.

Child 3: Mamma Mu cannot draw.
Researcher: She cannot draw?
Child 3: No, she has no hands.

The same reasoning where used for most of the artefacts and in the end this pair put none of the artefacts at Mamma Moo's end, instead they distributed them evenly between the middle category and Castor´s end. This pair did not change the position of the artefacts when they were introduced to the two books. But when the laminated Castor was replaced by the laminated Crow the children put all of the artefacts in the middle category, arguing that both of the characters used these.

Another factor that seemed important for all of the children when distributing the artefacts had to do with the characters as representations of a species.

Researcher: Do you believe that both use the pen? Or is it Castor who uses the pen? Or…
Child 2: Castor! Castor.
Child 1: Castor, because he builds.

Researcher: Castor builds?
Child 2: Yeah, he needs sticks and he thought that was a stick

So to recap, the level of anthropomorphism as well as the discernibility of the characters species seem to be important factors influencing the children.

Gender and Artefacts

There are studies showing that girls generally have less interest and self-confidence when it comes to technology (e.g., Mawson, 2010; Turja et al., 2009). In Mawson's survey (2010), the girls (aged 5-10) were slightly more likely to select domestic items as examples of technology. They also had more difficulty deciding on how to answer the questions.

In our pilot study, we could not recognise any differences between the boys' and the girls' answers or self-confidence. It was also clear that none of the children took into account a stereotyped gender perspective when they chose who used the different tools. Instead, crucial for their choices were book illustrations and movies. During the interviews all four children stated that both the male and the female main character (both anthropomorphic animals) were able to use the tools. On the other hand, sometimes Mamma Moo (a cow) was referred to as "he". One possible explanation is that the children unconsciously associated the tools (e.g., saw, hammer, drill) to the male domain. The question is whether the children had responded in the same way if we instead of anthropomorphic animals had used books with humans as main characters?

Moreover, when discussing ownership of the artefacts, we only used the images in the books, we did not read the stories. The result may have been different if we also had read the books and discussed the technological content on basis of context. For example, Mamma Moo is a character that somewhat violates prevailing norms. Although she is a cow she wants to do all the things the children do. Crow, however, is a conservative character, who wishes to be confirmed on the basis of his technological knowledge. Mamma Moo, on the other hand, solves technological problems because it makes her happy. Crow, in contrast, likes to flaunt himself and believes that the way Mamma Moo solves problems is not the correct way. He thinks of himself as superior when it comes to the field of technology. In the pictures Crow wears a cap with the text: "Crow Construction Limited" and his tree house is almost perfect compared to Mamma Moo's house. During one of the interviews, one of the children also noted that "Crow is a better builder".

Conclusions

Our pilot study indicates that that when there are anthropomorphic animals using different kind of tools, the children do not indicate in any explicit way that these artefacts are genderised. We also found that the 5-year-olds participating in the study did not have any direct concept of what technology is, but they had good knowledge of the various tools and their function. Building on previous research and the results from this pilot study, we intend to do the following:

1) Examine if children's books with human characters may have an impact on children's genderising of artefacts.
2) Examine in what way preschool children's interaction with everyday technological artefacts at home influences their genderisation and knowledge of said artefacts.
3) Examine whether preschool children can identify the function of an artefact from its design, even when using artefacts that they do not come in contact with in their daily life.

This will be done by using a larger sample of preschools and children. These will be represented by different regions, both urban and rural, as well as different cultural backgrounds.

References

Axell, C. (2015). *Technology Landscapes in Children's Literature. A Didactic Journey from Nils Holgersson to Pettson and Findus*. Dissertation. Linköping: Linköping University.

Axell, C. & Boström, J. (2015). Facts for Youngsters – Contextualised Technology or Fragmented Artefacts? A Study on Portrayals of Technology in Picture Books From a Gender Perspective. In M. Chatoney (Ed.), *PATT 29 Plurality and Complementarity of Approaches in Design and Technology Education*, April 6-10 (pp. 42-48). Marseille: Aix Marseille University.

Berner, B. (1999). *Perpetuum mobile? : teknikens utmaningar och historiens gång.* Lund : Arkiv.

Berner, B. (2003). Vad har teknik med genus att göra? In B. Berner (Ed.), *Vem tillhör tekniken?: Kunskap och kön i teknikens värld* (15-21). Lund: Arkiv förlag.

Braun, V. & Clarke, V. (2006) Using thematic analysis in psychology, Qualitative Research in Psychology, 3:2, 77-101

Crisp, T., & Hiller, B. (2011). 'Is This a Boy or a Girl?': Rethinking Sex-Role Representation in Caldecott Medal-Winning Picturebooks, 1938-2011. *Children's Literature in Education, 42*(3), 196-212.

Damber, U., Nilsson, J., & Ohlsson, C. (2013). *Litteraturläsning i förskolan*. Lund: Studentlitteratur.

DeLoache, J. S. (1991). Symbolic Functioning in Very Young Children: Understanding of Pictures and Models. *Child Development*, (4). 736.

Elster, C. (1994). Patterns within Preschoolers' Emergent Readings. *Reading Research Quarterly*, (4). 403.

Evangelou, D., Dobbs-Oates, J., Bagiati, A., Liang, S., & Choi, J. Y. (2010). Talking about Artifacts: Preschool Children's Explorations with Sketches, Stories, and Tangible Objects. *Early Childhood Research & Practice*, *12*(2),

Faulkner, W. (2001). The technology question in feminism: A view from feminist technology studies. *Women's studies international forum, , 24*(1), 79-95.

Faulkner, W. (2003). Teknikfrågan i feminismen. In B. Berner (Ed.), *Vem tillhör tekniken?: Kunskap och kön i teknikens värld* (23-52). Lund: Arkiv förlag.

Ganea, P. A., Canfield, C. F., Simons-Ghafari, K., & Chou, T. (2014). Do cavies talk? The effect of anthropomorphic picture books on children's knowledge about animals. *Frontiers in psychology*, *5*.

Gelman, S. A., & Bloom, P. (2000). Young children are sensitive to how an object was created when deciding what to name it. *Cognition*, *76*(2), 91-103.

Gooden, A. M. & Gooden, M. A. (2001). Gender representation in notable children's picture books: 1995–1999. *Sex Roles, 45*(1-2), 89-101.

Hamilton, M. C., Anderson, D., Broaddus, M. & Young, K. (2006). Gender stereotyping and under-representation of female characters in 200 popular children's picture books: A twenty-first century update. *Sex Roles*, *55*(11-12), 757-765.

Hellsing, L. (1999). *Tankar om barnlitteraturen*. (New ed.). Stockholm: Rabén & Sjögren.

Holbrook, A., Panozza, L., & Prieto, E. (2009). Engineering in Children's Fiction – Not a Good Story? *International Journal of Science and Mathematics Education*, *7*(4), 723-740.

Kelemen, D. (1999). The scope of teleological thinking in preschool children. *Cognition*, *70*(3), 241-272.

Klasander, C. (2010). Talet om tekniska system: Förväntningar, traditioner och skolverkligheter. Dissertation. Linköping: Linköpings universitet

Klinting, L. (2009). *Castor snickrar*. Stockholm: Alfabeta Bokförlag AB

Kåreland, L. (2013). *Barnboken i samhället*. (2nd ed.). Lund: Studentlitteratur.

Legare, C. H., Lane, J. D., & Evans, M. E. (2013). Anthropomorphizing Science: How Does It Affect the Development of Evolutionary Concepts? Merrill-Palmer Quarterly, 59(2), 168-197.

Martin, S. N. & Siry, C. A. (2009) Raising critical issues in the analysis of gender and science in children's literature. *Culture Studies of Science Education*, *4*(4), 951-960.

Matan, A., & Carey, S. (2001). Developmental changes within the core of artifact concepts. *Cognition*, *78*(1), 1-26.

Mawson, B. (2007). Factors affecting learning in technology in the early years at school. International Journal of Technology & Design Education, 17(3), 253-269.

Mawson, B. (2010) Children's developing understanding of technology. *International Journal of Technology and Design Education*, *20*(1), 1-13.

Mawson, B. (2013). Emergent technological literacy: what do children bring to school? *International Journal of Technology & Design Education, 23*(2), 443-453.

Mellström, U. (1999). *Män och deras maskiner*. Nora: Nya Doxa.

Mellström, U. (2003). Teknik och maskulinitet. In B. Berner (Ed.), *Vem tillhör tekniken?: Kunskap och kön i teknikens värld* (57-76). Lund: Arkiv förlag.

Milne, L. & Edwards, R. (2011) Young children's view of the technology process: an exploratory study, *International Journal of Technology and Design Education*.
Published online 12 May, 2012. DOI: 10.1007/s10798-011-9169-1

Nissen, J. (2003). Datorkulturen – en manlig historia. In B. Berner (Ed.), *Vem tillhör tekniken?: Kunskap och kön i teknikens värld* (77-92). Lund: Arkiv förlag.

Norman, D. (2002). *The design of everyday things*, New York: Basic Books.

Nyberg, A. C. (2003). Kvinnor som uppfinnare och innovatörer. In B. Berner (Ed.), *Vem tillhör tekniken?: Kunskap och kön i teknikens värld* (201-228). Lund: Arkiv förlag.

Oskamp, S., Kaufman, K. & Wolterbeek, L. Atchison. (1996). Gender role portrayals in preschool picture books. *Journal of Social Behavior and Personality, 11*(5), 27-39.

Outterside, Y. (1993). The Emergence of Design Ability: the Early Years. IDATER 1993 Conference, Loughborough, Loughborough University, 43-49.http://hdl.handle.net/2134/1574

Reynolds, K. (2011). Introduction. In K. Reynolds, K. & M.O. Grenby (Eds.), *Children's literature studies: A research handbook* (1-10). Basingstoke: Palgrave Macmillan.

Roden, C. (1995). Young Children's Learning Strategies in Design and Technology. IDATER 1998 Conference, Loughborough: Loughborough University, 21-27.http://hdl.handle.net/2134/1521

Simonsson, M. (2004). Bilderboken i förskolan: En utgångspunkt för samspel. Diss. Linköping: Linköpings universitet

Siu, K.W.M. & Lam, M.S. (2005). Early Childhood Technology Education: A Sociocultural Perspective. *Early Childhood Education Journal,* 32(6), 353- 358.

Skolverket. (2010). *Curriculum for the Preschool Lpfö 98. Revised 2010.* Skolverket/National Agency for Education. (2010). *Curriculum for the Preschool. Revised 2010.* Stockholm: Skolverket.

SOU 2006:75. (2006). *Jämställdhet i förskolan – om betydelsen av jämställdhet och genus i förskolans pedagogiska arbete.* Stockholm: Fritzes Offentliga Publikationer.

Svensson, M. (2011). Att urskilja tekniska system: didaktiska dimensioner i grundskolan. Diss. (sammanfattning) Linköping : Linköpings universitet, 2011. Norrköping.

Sørensen, K. H., & Berg, A. (1987). Genderization of Technology among Norwegian Engineering Students. *Acta Sociologica (Taylor & Francis Ltd)*, *30*(2), 151-171.

Trepanier-Street, M. L. & Romatowski, J. A. (1999). The influence of children's literature on gender role perceptions: A reexamination. *Early Childhood Education Journal, 26*(3), 155-159.

Turja, L., Endepohls-Ulpe, M., & Chatoney, M. (2009). A conceptual framework for developing the curriculum and delivery of technology education in early childhood. *International Journal of Technology & Design Education, 19*(4), 353-365. doi: 10.1007/s10798-009-9093-9

Vries de, M. (2006). Technological Knowledge and Artifacts. J.R. Dakers (Ed.), *Defining Technological Literacy: Towards an Epistemological Framework* (17-30). New York: Palgrave Macmillan.

Wieslander, J. & Nordqvist, S. (2010). *Mamma Mu bygger en koja.* Natur och kultur.

The Role of Ontological Design in an Object-Led 21st Century Skills Curriculum

Jennifer Bain,
Goldsmiths
University of London
j.bain@gold.ac.uk

Abstract

This paper offers an alternative approach to the development of 21st Century skills by exploring the role that objects might occupy in the learning process. Through drawing on the fields of ontological design, material culture and critical pedagogy, the paper offers a conceptual learning space for 21st Century skills, which claims the 'user' as learner and the 'object' as teacher. The paper goes on to illuminate how designers might be central to a 21st Century 'object-led' skills curriculum and concludes by suggesting how design educators might help shape this curriculum by considering ontological design as an integral component of design practice.

The paper draws on a small-scale research study organised in two phases. The first phase of the research examines the literature to reflect on the object-subject relationship, building on the concept that 'artefacts bear meaning, communicate and signify beyond themselves' (Tilly, 2007, p258) and, as such, have direct impact on the human condition (Latour, 1996; Sage, 2004; Tilly, 2007). This theoretical exploration posits that our behaviours, and associated skills, are increasingly influenced by design; we design our world, whilst that world 'acts back on and designs us' (Willis, 2006, p80). Alongside this, rapid technological advancements mean that designers increasingly speculate a future where objects are less static, reacting to and interacting with humans (Antonelli, 2011; Dunne and Raby, 2013).

The second phase of the research study is an evidence-building case study with a dual focus. Firstly, users are interviewed and observed to develop understanding of how object-subject interactions can form the basis of a conceptual learning space where situation is 'inseparable from interaction' (Dewey, 1938, p41), adding materiality – the world of artifacts and things- into the cognitive equation (Malafouris, 2013). Secondly, design students and design educators are interviewed to consider how ontological design might become a more conscious act, with 'design as the practice of social construction' (Tonkinwise, 2011, p4) at its core.

Introduction

This paper discusses a small-scale exploration of how design educators might consciously and explicitly consider the role objects might occupy in the learning process as integral to 21st century learning. It examines the role of design agency in order to argue that we should re-conceptualise the designer as educator, suggesting ontological design might become a more conscious act, with 'design as the practice of social construction' (Tonkinwise, 2011, p4) at its core. The paper concludes by suggesting an approach that supports designers to design objects that consider an epistemological theory of experiential learning (Dewey, 1938) alongside more contemporary theories of learning.

Phase 1 – The Object-Subject Relationship

In an era of rapid technological advancement, we see more regularly the exploration of the object-subject, where researchers, theorists, designers and educators increasingly speculate a future based on the notion that objects are not static but capable of responding to humans (Antonelli, 2011; Dunne and Raby, 2013; Tilly, 2007; Rose, 2005; Malafouris, 2013). Many contribute to a shared vision that design is more pervasive than we understand and can influence us as users through a form of interaction. For example, Jonathan Chapman (Chapman, 2005) in 'Emotionally Durable Design', and Shelly Turkle in 'Evocative Objects' (Turkle, 2007).

Bruno Latour suggests that in order to better understand our social being we must introduce and welcome nonhuman actants. Actor Network Theory (ANT) (Latour, 1996), recognises nonhuman actants as being fundamental to understanding how 'things' are connected. Here, an actor 'is any agent, collective or individual, that can associate or disassociate with other agents' (Sage, 2004). ANT provides an opportunity to re-categorise a typology of design by creating networks that allow us to de-centralise the subject of study and, as opposed to studying the human as an isolated being, one can begin to study situations, including learning situations, by focusing on what relates and connects a sequence of actions or objects. Latour suggests 'I have sought to show researchers in the social sciences that sociology is not the science of human beings alone... Our collective is woven together out of speaking subjects, perhaps, but subjects to which poor objects, our inferior brothers, are attached at all points' (Latour, 1996: p.viii). This is useful in repositioning the stance of the designer in order to study beyond the 'user', considering the object alongside the subject in order to be able to recognise influential factors, connecting distant or seemingly abstract causes to specific issues. Shove further develops this notion of objects signifying and communicating beyond themselves, suggesting 'There is no doubt that social lives have things, that things have social lives' (Shove, 2007: p.4). Whilst Tilly suggests that material culture has the potential to become a text to be 'read' and a 'semiotic discourse to be decoded' (Tilly, 2007: p258), establishing objects as fundamental components of meaning and communication in everyday lives and, thus, having the capacity to claim a role as 'teachers'.

Building on this concept of object as teacher, it is possible to posit that behaviours and associated skills are increasingly influenced by design practice that might be termed 'ontological design' (Willis, 2006). Ontological design seeks to reconsider design, moving away from a notion of design as 'effectively a discipline that deals with relations in both the human and non-human realms, but the lenses that designers use are one-way, entrenched firmly in a human-centric ('Correlationist') foundation' (Ansari, 2013: p.5). Rather, ontological design claims that in design a double movement occurs. In effect 'we design our world, while our world acts back on and designs us' (Willis, 2006),

suggesting a reciprocal relationship that influences our pre-conditioned assumptions and interpretations. 'Ontological designing, then, is concerned with the nature and agency of design, which understands design as a subject-decentred practice, acknowledging that things as well as people design' (Willis, 2006: p.81). Object Orientated Ontology (Harman, 2011) and ontological designing both strongly advocate decentralising the subject in order to not privilege the human. In this they move beyond ANT, which similarly decentralises the subject by focusing on a network (and therefore a series of actants), yet still privileges the human. Therefore, it might be argued that ontological design offers a way forward for design practice with object as teacher at its core, questioning how we are influenced, shaped and designed by objects, to consider how 'As we form and deform the processes of world formation, we are equally transforming what we ourselves are and will become as human beings' (Fry, 2012: p.197).

The need for ontological design to become a more conscious act is perhaps more pertinent than ever in this era of rapid technological advancement, an era in which many design thinkers, such as Paola Antonelli (2011), speculate a future based on objects that have the capacity to respond, react to and interact with humans. Tony Dunne and Fiona Raby use speculative methods in an attempt to provoke critical awareness in their audience, getting them to question their assumptions and interpretations of the objective world. They suggest that speculative design can act as 'a catalyst for collectively redefining our relationship to reality' (Dunne and Raby, 2013: p.2). Jonathan Chapman (Chapman, 2005) in 'Emotionally Durable Design', and Shelly Turkle in 'Evocative Objects' (Turkle, 2007) also contribute to a shared vision of design that is more pervasive, capable of influencing users through a form of interaction.

This, in a learning context, may be considered as object agency. Here, agency is understood simply as the ability to act. Actions become expressive of a particular agent, in this case the object, 'ultimately insofar as the agent uses uncoerced decision-making powers to choose between alternatives based upon an understanding of circumstances and options available' (Borgerson, 2005: p.441). Agency, therefore, might be contrasted to unthinking, deterministic processes. Similarly, as opposed to the user taking control over the object, Tilly suggests that 'things may be attributed agency, not in the sense that they have minds and intentions, but because they produce effects on persons' (Tilly, 2007: p.260). This suggests that, in learning processes, we might consider that both humans (subject) and non-humans (object) have the ability to act, make decisions or form judgements. Whilst objects have been used to support teaching and learning since the earliest days of art and design education, for example through 'object-centred' or 'object-based' learning (Paris, 2002), understanding of 'user' as learner and 'object' as teacher is less well developed.

Thus, in concluding phase 1 of the research study, it is possible to argue the need to explicitly examine what might be termed 'object-led pedagogy'. Pedagogy that, in common with ontological design, de-centralises the human subject to both explore the pedagogical agency of objects and the role of designers in considering this as part of design praxis. Here praxis is defined as 'informed, committed action', it is not simply action based on reflection (Friere, 1970; Carr and Kemmis, 1986: p.190). It is action which embodies certain qualities, recognising the role and responsibility designers have in 'acting futurally' (Fry, 2012: p.224). Accordingly, this paper moves to focus on phase 2 of the research study, an evidence-building case study.

Phase 2 – An Evidence Building Case Study

The second phase of the research is an evidence-building case study with a dual focus. Firstly, a sample of five users will be interviewed and observed to develop understanding of how object-subject interactions can form the basis of a conceptual learning space where situation is 'inseparable from interaction' (Dewey, 1938: p.41). Secondly, a sample of five design students and five design educators will be interviewed to consider how ontological design might become a more conscious act, and how this might draw on more contemporary theories of learning, such as Transformative Learning (Mezirow, 2009) and Expansive Learning (Engestrom, 2009) to develop practice. As the research is ongoing, this paper reports on early analysis of data.

User Interviews and Observation Findings

Building on the concept of object-led pedagogy as developed in phase 1 of the research study, observations and interviews are focused on exploring a conceptual learning space, drawing on Dewey's premise that, in experiential learning, every form of interaction can be considered to be an actant that is relevant. 'The two principles of continuity and interaction are not separate from each other. They intercept and unite. They are, so to speak, the longitudinal and lateral aspects of experience' (Dewey, 1938: p.42). Thus, the collection and analysis of data focused on exploring this principle, by speculating that each interaction might be considered a learning connection between object and subject (user) while continuity might be considered as repetition, or use, over time, see figure 1.
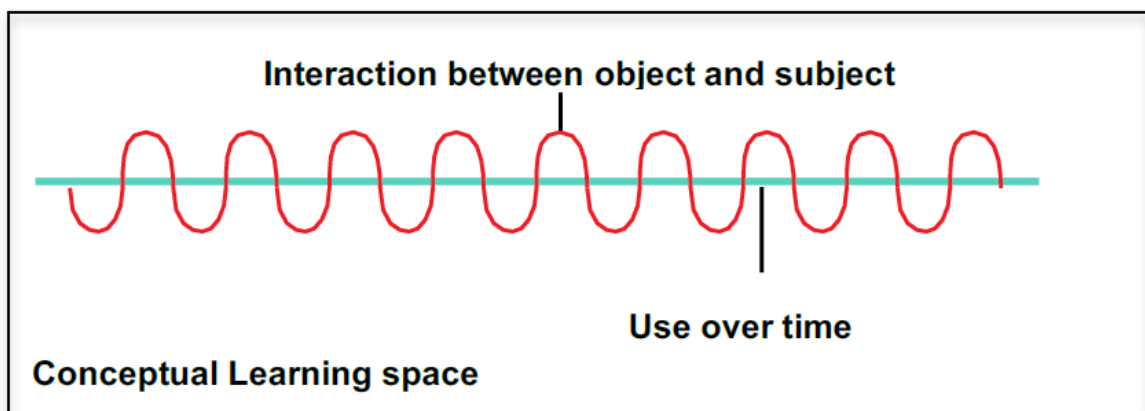
Figure 1: Object-led learning

Using a pragmatic methodology, looking at the way different worldviews derive from lived-experiences (Robson, 2012), observations will be conducted over a longitudinal time-frame of six months, in a variety of natural settings (learning spaces), such as home and workplace, and with a variety of objects, see figure 2. Semi structured interviews will be conducted with participants at three points, 0 months, 3 months and 6 months.
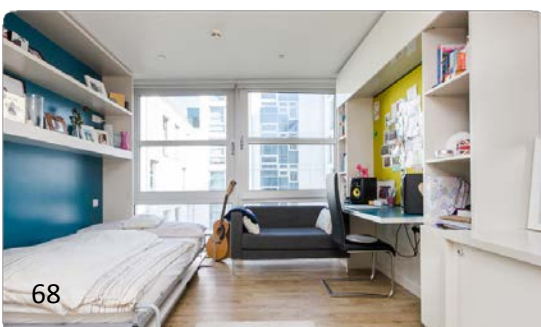
Figure 2: Observation setting and object selection

Initial analysis of data from user interviews and observations reveal two key findings. Based on phase 1, coding categories are developed to support a focus on the interaction, or dialogue, between the object toward the subject, in effect how and in what form of communication occurs in the conceptual space between human and object. Data was coded under the following themes:

 1.Object   **2.**Situation   **3.**Interaction   **4.**Behaviour   **5.**Agency   **6.**Learning

In keeping with the phase 1 literature review, early user observation and interview data appears to confirm the potential of a range of objects to produce effects on subjects/users (Tilly, 2007). Consistent with more formal participatory learning environments, the objects appear able to stimulate curiosity and ongoing interest through 'object-centred' or 'object-based' learning (Paris, 2002), particularly when this is planned and considered explicitly by the subject. However, perhaps of most interest is confirmation that, when the interaction between the object and subject is part of everyday activity, user behaviours and associated skills appear to be directly influenced by the object. Examples of how objects appear to 'teach' subjects include:

- Dependence to fill gaps in knowledge

- To use logic to adapt if a situation or problem occurs

- How to make better choices

- Reveal a lack of understanding

- Reliance for social contact

- Increased physical strength

This is consistent with the reciprocal relationship claimed by ontological design where designed objects act back on and designs the subject (Willis, 2006). This leads to a focus on examining how participants were influenced, shaped and designed by the objects. Data reveals that users were able to recognise some of the 'learning' that had had taken place and identify in advance that such learning was likely to happen. This is illustrated by the following exchange:

Interviewer: So do you recognise that you learn through everday interactions with [object D: an ipad]?

User 4: Well, we're bound to aren't we? Everytime I use the ipad I know I will get better at typing, at flicking the page. It becomes intuitive, so I've clearly learnt from it.

69

However, users were less able to identify other types of learning, particularly where they did not see possibilities for learning or where they were unaware that learning had taken place. This 'hidden' learning was identified through analysis of observation data from **User 3**, that revealed a a dependence on technological objects for social interactions that was not recognised by the user when interviewed.

This highlights a complexity to object-subject interaction in the context of learning. This complexity is of relevance when considering how object-led pedagogy might form part of ontological design practice, and appears to be consistent with what Norman terms 'affordances' (Norman, 2002), developed in the context of human - machine interaction to refer to action possibilities. Gaver develops this concept, dividing object affordance into three categories: perceptible, hidden, and false. An affordance that is perceptible refers to information that an actor is able to to perceive and then act upon (Gaver, 2011). A hidden affordance, however, indicates that there are possibilities for action, but the actor does not perceive these. A hidden affordance could then be compared to an object's secondary function, which hasn't been designed with intent by the designer, although, as in the case of **User 3**, communicates and teaches the user something almost accidental in nature. Although early analysis of data does not reveal specific examples of false affordance, affordance that doesn't have any real function or meaning - yet the actor perceives nonexistent possibilities for action (Gaver, 2011), it is worth considering as part of future analysis.

As part of an object-led pedagogy, this early finding suggests that when affordances are perceptible, they offer a direct link between perception and action, and when affordances are hidden or false, they can lead to mistakes and misunderstandings. Consequently, this would imply that hidden and false affordances need to be explicitly considered as part of ontological design practice.

Early analysis of data also focused on subject-decentering, placing the dialogue from the object to subject in the foreground. Further analysis of data around forms of communication that occur in the conceptual learning space identified 3 specific features of designed objects which appear to have most influence on the subject in terms of understanding, habits and capabilities, namely:

- Aesthetics

- Function

- Ergonomics

Aesthetics

User interview data reveals that object aesthetics appear to evoke interpretation and emotion. Observation data also reveals aesthetics as an underlying cause of misinterpretation, or false affordance, around value, meaning and purpose. Whilst authentic value and meaning can be developed through interactions with the object, aesthetics appear to influence and lead to interpretations before interaction has taken place. This places aesthetics as the first line of perception. User interview data indicates that aesthetics play a central role in the decision to interact. This is illuminated by the following extract:

User 5: I often base my choice [of object] on how it looks. Especially if I've had something similar before that's been easy to use, or it's familiar reminding me of happy times. If something looks difficult to use or ugly, then, for sure, I'm likely to avoid it….

This suggest that familiarity acts as a symbolic reference, whilst materials and forms engage the imagination of the user to support assumptions of function, quality and other features. Perception and interpretation appear to come before any physical interaction and a judgement is made whether to interact or not. In the context of the conceptual learning space outlined in figure 1 above, this implies aesthetics is a key factor in engaging the user (learner) to interact with the object (teacher).

Function

Data analysis reveals function as a key driver of user and object interaction. It is a central component in guiding the user into a pattern of habit. In turn, habitual patterns appear to influence the user's (learner's) worldview. This implies that function may be pivotal in developing desired learning, or object-led learning objectives, 'Take the habituating design away, or reintroduce some obstacles or costs, and such behaviors quickly evaporate' (Tonkinwise, 2011: p.5). It is interesting to consider this in terms of earlier finding around affordances. That is to say, the habituating design Tonkinwise (2011) refers to might be considered a perceptible affordance activated through the function of the object, whereas data from this research study indicates that habituating design often relies on hidden affordances. Data indicates that this appears particularly true of technological devices.

Ergonomics

Ergonomics was revealed as another feature of design that has a strong influence on learning through objects. The data reveals that ergonomic features of an object influence how the user is engaged and challenged. For example, physically challenging interactions act back (Fry, 2012) in designing the user to be more physically capable. This reveals the potential for designed object-led learning to change the subjects physical capabilities beyond which we currently understand, 'when a designer postulates a bicycle that cannot (yet) be ridden or a chair that cannot be manufactured, shipped, or sat upon, it is not because he is ignorant of ergonomics but because he understands that the measurement of the human body is no substitute for the investigation of the human condition' (Lukić and Kātz, 2011: p.XXV).

Whilst, as emphasised earlier, data analysis is at an early stage, there appear to be some interesting early conclusions to be drawn. Firstly, user interviews and observations confirm the potential of object-led pedagogy in forming the basis of learning connections, or interactions, between object and subject in a conceptual learning space. Secondly, the potential of designed objects to act as 'teacher' must be considered in terms of perceptible, hidden, and false affordances. Lastly, that designers must consider how features of designed objects, such as aesthetics, function and ergonomics, have influence on the subject (learner) in terms of understanding, habits and capabilities.

Designer and Design Educator Interview Findings

Design student and design educator interviews are informed by user interview findings, as revealed above. The primary focus of these interviews is to consider how ontological design might become a more conscious act in order to consider and develop object-led pedagogy and to explore how this

might draw on a range of theories of learning. Again, as the research is ongoing, this paper reports on early analysis of data.

Interview data confirms that both design students and design educators consider that designing takes shape in many forms such as; planning, thinking, considering, making, improving, prototyping, testing, probing, quantifying, judging, inventing. However, few yet identify consideration of object-led learning as a concern. Interestingly, data reveals that when introduced to the concept of object-led pedagogy all participants recognised both its potential and its importance.

Design Student 2: I've never really considered how what I design might be able to 'act-back'. Now you mention it, I've never really thought that through in terms of how designed objects influence my behavior or habits. I guess I know I spend too much time on my phone…. That's a bit scary to think of that power… but then it's scary to have that power and not think about it or be aware of it.

Design Educator 5: We do teach our students to consider the impact of their practice, but not explicitly in terms of object-led learning as you describe it. It's difficult to conceive how to understand the impact of a design beyond the intention of the designer…. But I can see how important it will be.

Furthermore, data analysis reveals, that when introduced to concepts such as 'The Ontology of Prototyping' (Tonkinwise et al., 2015) where prototyping activities highlight the impact designers have in determining agency, participants started to consider how ontological design for object-led pedagogy might be possible.

In addition, participants valued and understood the role that speculative design, as discussed above, might have in considering the impact of designed objects beyond the intention of the designer. That is to consider 2nd order design, which might be termed the unintended or unforeseen impact of designed objects on users (Willis, 2006; Fry, 2012; Tonkinwise, 2015). Discussions around consideration of possible futures, using as an example Dunne and Raby's (2013) cone of preferable futures, see figure 3 below, resulted in participants revealing they saw the potential of such an approach in teaching and learning ontological design.

CONE OF PREFERABLE FUTURES
BASED ON STUART CANDY'S DEPICTION
DUNNE & RABY, "SPECULATIVE EVERYTHING"
MIT PRESS 2014
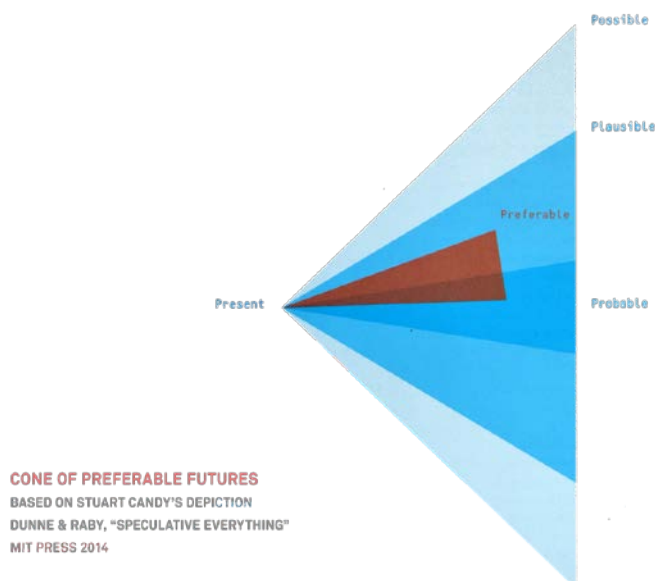
Figure 3: Cone of Preferable Futures

In, conclusion, analysis of design student and design educator data is at an early stage. What has emerged from early analysis are three initial findings. Firstly, that all participants recognise the potential and importance in learning and teaching around ontological design. Secondly, that whilst they recognise the complexity of concepts such as affordances, when introduced through more familiar concepts, such as aesthetics, function and ergonomics, they identify that ontological design learning becomes more accessible. Lastly, that a key approach to developing ontological design learning appears to be in differentiating between 1st order design, where it is the designer takes responsibility for the design form and function, and 2nd order design, as described above.

Final Conclusions

Early findings from this small-scale research study appear to be useful in a range of ways. Firstly, both phase 1 and phase 2 confirm the potential to develop more considered object-led pedagogy. Secondly, both phase 1 and phase 2 findings reveal a range of ways that the complexity of such object-led pedagogy might be considered, revealing a key role for designers and design educators. Lastly, the research underlines the necessity to explore such pedagogy, illuminating the potential of object-led learning to impact on individuals and societies.

In closing, it is suggested that a central challenge for the remainder of this study, and for further research, is to develop ontological design for object-led pedagogy that might move beyond 'design as the practice of social construction' (Tonkinwise, 2011: p4) to consider more contemporary theories of learning, such as Transformative Learning (Mezirow, 2009) and Expansive Learning (Engestrom, 2009) in its practice. This means that consideration should be given to both 1st and 2nd order design that develops more critical humanist pedagogy as revealed in figure 4 below.

As we move along the line from Behaviourism to Critical Humanist perspectives, the theories become less concerned with control and prediction and more concerned with social

Theories of Learning

Theories/Perspectives

73

assessment.
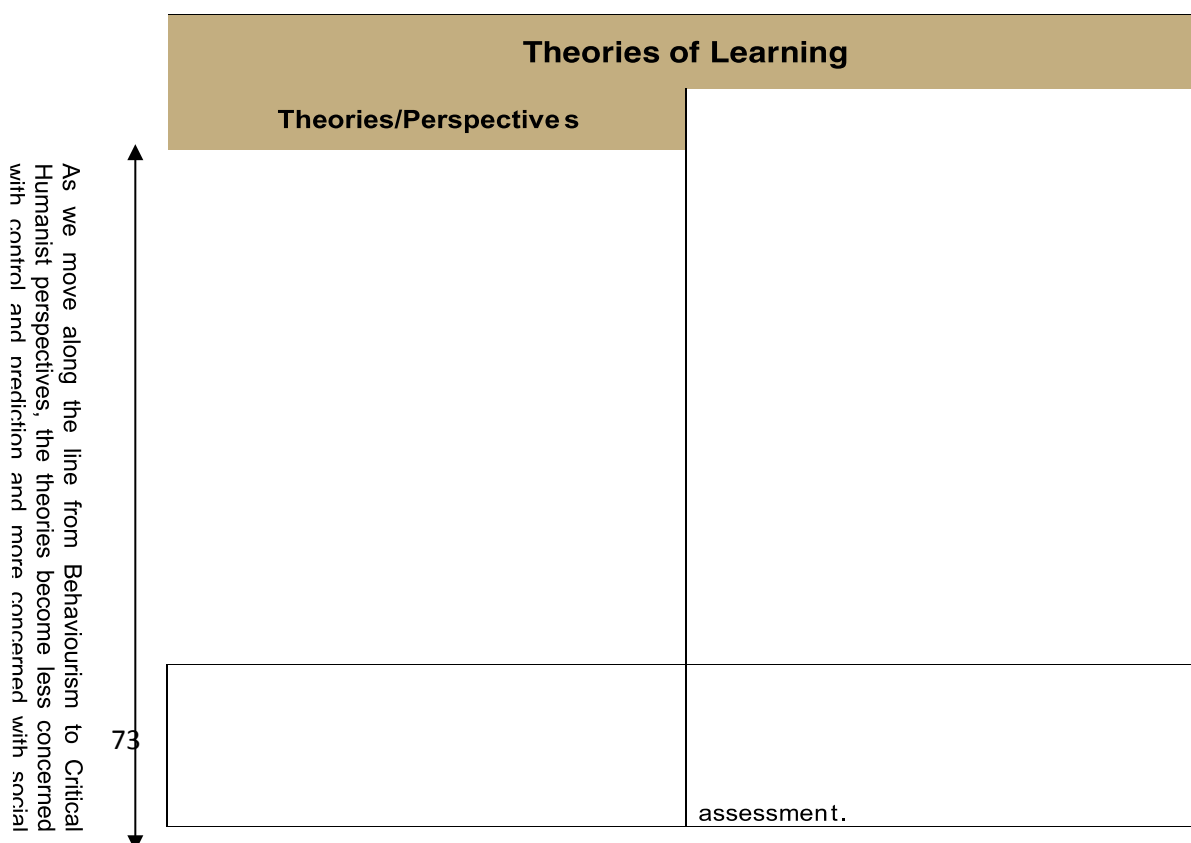
Figure 4: Theories of Learning (adapted from Brown (2004))

This, it is argued, is of central importance to those designers and design educators interested in object-led pedagogy that is both considered and critical, less concerned with control and prediction, but, rather, concerned with independent and empowered learners. It is argued that such research is a crucial part of praxis, the informed, committed action that recognises the role and responsibility designers have in 'acting futurally' (Fry, 2012: p.224).

References

Ansari, A. (2013). The Flat Earth Object Oriented Ontological Explorations in Design Praxis. Theses, [online] (Paper 51). Available at: http://repository.cmu.edu/theses/51/ [Accessed 5 Jan. 2016].

Antonelli, P. (2011). Talk to me. New York, N.Y.: Museum of Modern Art.

Borgerson, J. (2005). Materiality, Agency, and the Consitution of Consumng Subject: Insights for Consumer Research. Advances in Consumer Research.

Brown, G. (2004). How Students Learn, A supplement to the RoutledgeFalmer Key Guides for Effective. Teaching in Higher Education series

Chapman, J. (2005). Emotionally durable design. London: Earthscan.

Dewey, J. (1938). Experience and Education. London: Collier MacMillan.

Dunne, A. and Raby, F. (2013). Speculative everything. Cambridge, Massachusetts: The MIT Press.

Engestrom, Y. (2009). Expansive learning: toward an activity-theoretical reconceptualization, in K. Illeris(eds.) *Contemporay Theories of Learning*, 53-73. Oxford: Routledge.

Friere, P. (1970). Pedagogy of the Oppressed. London: Penguin`

Fry, T. (2012). Becoming Human by Design. London: Berg.

Gaver, W. (2011). The Affordances of Media Spaces for Collaboration. Cambridge: Rank Xerox

Latour, B. (1996). Aramis, or The Love of Technology. London: The MIT Press.

Malafouris, M. (2013). How things Shape the Mind. Cambridge, Massachusetts: The MIT Press.

Mezerow, J. (2009). An Overview on Transformative Learning, in K. Illeris(eds.) *Contemporay Theories of Learning*, 90-105. Oxford: Routledge.

Norman, D. (2002). The design of everyday things. New York: Basic Books.

Rose, D. (2005). Enchanted objects. London: Sage Publications Ltd.

Sage, (2004). A-Ritzer-Encyclopedia. [online] Available at: http://www.sagepub.com/sites/ [Accessed 26 Aug. 2015].

Shove, E. (2007). The design of everyday life. New York, NY: Berg.

Tilly, C. (2007). Ethnography and Material Culture. In: P. Atkinson, A. Coffey, S. Delamont, J. Lofland and L. Lofland, ed., Handbook of Ethnography, 1st ed. London: Sage Publications Ltd.

Tonkinwise, C. (2011). I (heart) Sustainability (because necessity no longer has Agency). Design Philosophy Papers, (2).

Tonkinwise, C., Fairfax, D., Feltham, O., Loo, S., Waller, M., Scott, K., Wildman, G. and Durrant, N. (2015). Ontology of the Prototype.

Turkle, S. (2007). Evocative objects. Cambridge, Mass.: MIT Press. Willis, A. (2006). Ontological Designing. Design Philosophy Papers, 4(2).

Willis, A. (2006). Ontological Designing - Laying the ground. In Design Philosophy Papers 3 (1), pp. 80–98

Modernisation of the school D&T curriculum with special reference to disruptive technologies; a case study of trainee teachers' responses

David Barlex, Independent researcher, The Strand, Brighton Marina, UK
david.barlex@btinternet.com

Nick Givens, University of Exeter, Graduate School of Education, UK.
N.Givens@exeter.ac.uk

Alison Hardy, School of Education, Nottingham Trent University; UK;
Alison.hardy@ntu.ac.uk

Torben Steeg, Independent Consultant
Independent researcher, Chorlton, Manchester UK,
torben@steeg.co.uk

Key words

School design & technology curriculum, modernization, disruptive technology, teacher education, peer teaching

Abstract

New and emerging technologies are a feature of the design & technology National Curriculum (for pupils aged 5-13 years) in England and the proposed new GCSE design & technology course (for pupils aged 14-16 years). These features are part of the modernisation of design & technology that is taking place in England. This paper reports a small case study of an 'understanding new and emerging technologies' activity in which trainee design & technology teachers at a university in England were required to research particular disruptive technologies (Barlex, Givens & Steeg 2015), develop presentations about these technologies to the other trainees undertaking the activity who then had to summarise their understanding of each disruptive technology in a short piece of writing (around 600 words) dealing with both the nature of the technology and its potential to be disruptive. In addition they had to justify its inclusion and suggest how it might be taught. The paper will describe the responses of the trainees, consider the extent to which they found this work challenging and comment on the way in which an understanding of such technologies might be taught to secondary school pupils as part of a modernised design & technology curriculum which develops the essential 21st century skill of technological perspective.

Introduction

The National Curriculum in England (DfE 2013) and the new GCSE for design & technology which will be taught from September 2017 (DfE 2015) require the teaching of new and emerging technologies. This requirement to teach explicitly about new and emerging technologies is new for English teachers of D&T. The Disruptive Technologies Project (Barlex, Givens & Steeg 2015) argues that it makes sense to identify these technologies with those that are likely to be disruptive. The Project aims to provide teachers with information about a range of new technologies alongside support on how to teach about these technologies within D&T. The question driving this case study is "To what extent does an introduction to disruptive technologies enable trainee teachers to engage with the modernisation of the schools design & technology curriculum". This is an important question because curriculum development in school departments that are traditional in their approaches to design & technology often fall to new entrants to the profession

Questions emerging from the driving question are concerned with the impact of the information provided by the Disruptive Technologies Project and the extent to which a) it helped the trainee teachers learn about disruptive technologies, their applications and impact and b) whether the idea of disruption (as defined within the Project) is sufficient to enable the trainees to explore the disruptive potential of new technologies.

Disruptive Technologies

The McKinsey Global Institute (Manyika et al, 2013) has suggested some features that mark out a technology as having the potential to be disruptive.

- They upset the status quo, for example overturning existing hierarchies and offering the possibilities of both more and less democratic hierarchies.
- They alter the way people live and work, for example increasing or decreasing employment opportunities, changing the knowledge and skills required for certain kinds of employment, shifting the expectations of education systems and altering relationships
- They reorganise financial and social structures, for example by redistributing financial rewards towards those who are deploying these technologies.
- They lead to entirely new products and services.

Disruptive technologies in D&T education

Barlex, Givens and Steeg (2015) have identified nine technologies that meet the McKinsey criteria and are suitable for consideration within design & technology education. These are shown in Table 1.

Table 1 Disruptive technologies for the school design & technology curriculum

The technology	The description
Additive manufacturing (AM)	AM involves fabricating physical objects in successive thin horizontal layers, according to digital models derived from CAD designs, 3-D scans or video games. Such printing can takes place at different scales from nano structures to complete buildings and may involve a wide range of materials: human tissue, electronics, and food as well as traditional industrial product materials such as polymers, metals and ceramics.
Artificial intelligence (AI)	AI can be categorized at three different levels. First is 'narrow' AI that specializes in one area e.g. the AI that plays chess better than humans. The second and third levels are concerned with more general ability. 'General' AI can perform as well as a human across the board i.e. it is AI that can perform any intellectual task that a human can. Such AI is yet to be developed. Third is 'super intelligent' AI i.e. an AI that performs better than human brains in practically every field. This has yet to be developed but several prominent scientists and technologists (including Stephen Hawkin, Elon Musk, Bill Gates, The Observer 2015) have warned that this carries with in an existential threat for the human race.
Augmented reality (AR)	Augmented reality (AR) is a live, direct or indirect view of a physical real-world environment whose elements are augmented (or supplemented) by computer generated sensory input such as sound, video, graphics or GPS data.
Big data	Big data is data that exceeds the processing capacity of conventional database systems. The data is too big, moves too fast, or doesn't fit the strictures of standard database architectures. It is collected by large corporations and governments (and, increasingly, open data

	from 'citizen' scientists) and when interpreted using big data analytics it can be used to give insights into the behaviour of potential consumers and citizens. It is the ability to cross-reference large data sets and thus draw inferences that don't actually appear in any of the individual data sets that gives rise to concerns that the availability of such data and its analysis will invade people's privacy and lead to mass manipulation
Internet of things (IoT)	The Internet of Things (IoT) is the networking of physical objects i.e. things that have embedded within them electronics, software and sensors which are connected to one another over the Internet and can exchange data. This allows extensive communication between the physical and digital worlds, enables remote control of devices across the Internet and produces vast amounts of big data.
Neurotechnology	Neurotechnology is concerned with technologies that inform about and influence the behaviour of the brain and various aspects of consciousness. Current neurotechnologies include various means to image brain activity, stimulation of the brain by magnetism and electricity, measuring the electrical and magnetic brainwave activity, implant technology to monitor or regulate brain activity, pharmaceuticals to normalize erratic brain function, and stem cell therapy to repair damaged brain tissue. Recently measurements of brain activity have been used to control real world artefacts.

Programmable matter	Programmable matter, is matter which has the ability to change its physical properties (shape, density, elasticity, conductivity, optical properties, etc.) in a programmable fashion, based upon user input or autonomous sensing.
Robotics	A very basic definition of a robot is "a machine that automates a physical task". This is limited because it gives no indication as to the intelligence and autonomy of such a machine. A microwave cooker automates the task of heating food but is simply responding according to instructions selected from a menu of pre-programmed instructions. So a more appropriate definition is "a machine that carries out a physical task autonomously using a combination of embedded software and data provided by sensors". This definition embraces relatively simple robots such as the Roomba vacuum cleaner to extremely complex robots such as the google self-driving car.
Synthetic biology	Synthetic biology is the process of designing and creating artificial genes and implanting them in cells. In some cases all existing genes have been removed; in others the new genetic sequences are introduced into the DNA of existing cells. It is far more than simply borrowing existing genes from nature. Synthetic biology is the process by which completely new life forms, i.e. life forms that have never previously existed, are created. Proponents of synthetic biology, such as David Willets (2013) when he was UK Minister for Science, argue that the technology could "fuel us, heal us and feed us" but are concerned that there is the possibility of public rejection as was the case in the UK with GM food.

They justify the identification of new and emerging technologies with disruptive technologies on the grounds that it is important for young people to study those technologies that are likely to have a significant effect on their lives in the short and medium term. A website to support the

consideration of these technologies in the secondary school design & technology curriculum went on line in March 2016, (Barlex, Givens & Steeg 2016) which includes a Teachers' Guide to disruptive technologies. This Guide elaborates five suggested ways in which teachers might approach teaching about disruptive technologies:

1. Through case studies

These allow pupils to find out about how a disruptive technology works, what it is being used for and how it affects society, the environment and peoples' lives.

As well as describing potential sources for case study material and advice on how to frame the structure of a case study, the Guide suggests ways in which pupils' interactions with case study materials can be made active.

2. Through designing without making

Building on the Young Foresight Project (Barlex 2012) and incorporated into England's National Strategies for design & technology (Department for Education and Skills 2004), designing without making is now a fairly well-established approach to helping pupils envisage the sorts of products and services that might derive from the deployment of a particular (in this case, disruptive) technology – especially those that for reasons of cost, safety, accessibility etc. are not easy to bring into a school environment.

3. Through designing and making

Noting that, at present, the disruptive technologies most amenable to this kind of approach, given the kinds of tools that schools currently have access to, are additive manufacturing, robotics, the Internet of Things and augmented reality.

4. Through making without designing

Activities in which pupils make artefacts that someone else has designed allow pupils to develop particular making skills without the distraction of design activity or the problems that might be caused by trying to make something they have designed but that is too demanding with regard to their current level of making skill. Some disruptive technologies can be used for making without designing. Printing an item designed by the teacher in order to learn how to use the 3D printer for example. Or building a simple robot from a kit of parts following instructions provided by the supplier.

5. Through considering consequences

The Guide suggests four approaches to considering consequences:

   a) Considering winners and losers

Examining consequences by asking "Who wins?" and "Who loses?" when a particular technology is deployed. This approach is amenable to pupils at the start of secondary education and useful as it immediately enables the technology to be scrutinised from the perspectives of different stakeholders and reveals to students that the way technology and society interacts is not straightforward.

   b) Using the Mckinsey criteria

These are noted earlier and provide a set of lenses through which to view the technologies so that they can adopt a constructively critical perspective.

   c) Exploring the life cycle of a technology

Technology teachers are well versed in helping young people consider the so called 'life cycle' of products and have used such teaching to engage students in the environmental impact of not only the manufacture of products but also their use and disposal as a critique of consumerism and the need to move from a linear to a circular economy (McArthur 2015). Exploring the emergence of a technology, its adoption and impact on society is less familiar territory and we introduce the the Gartner 'Hype' Cycle (Gartner 2015) as an attempt to chart the life of a technology. It provides

a graphic representation of the maturity and adoption of technologies and applications, and how they are potentially relevant to solving real business problems and exploiting new opportunities.

   d)   Exploring and building scenarios

A general approach often used to present or build scenarios is to identify two sets of so called 'critical or significant uncertainties' and to use these as axes to create four quadrants such that located in each quadrant there is a particular scenario (see Figure 1). Each of these can be fleshed out into a human story which can be explored from various perspectives.

High engagement with 3D printing
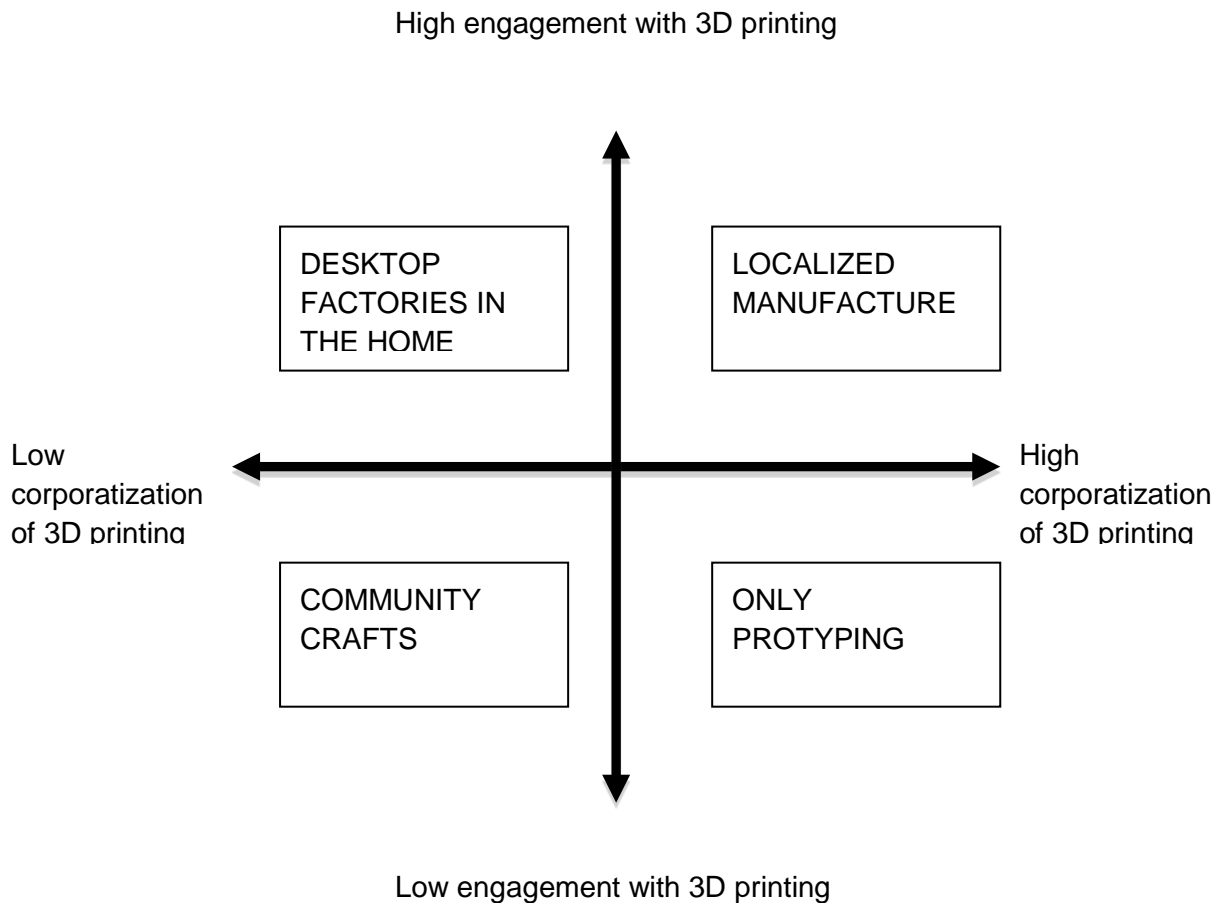
Figure 1: Four scenarios based on axes of uncertainty concerning 'Engagement with 3D printing' and 'Corporatization of 3D printing' (from Birtchell et al 2012)

In order to prepare undergraduate trainee teachers[1] for teaching in this area a university in England required that trainees consider a disruptive technology as part of the programme of study and justified this in terms of a) the need for the design & technology curriculum to modernise, b) the inclusion of new and emerging technologies as part of this modernisation and c) that it makes sense to use potentially disruptive technologies as the example of new and emerging technologies. Each trainee was assigned at random one of the disruptive technologies identified by Barlex et al (ibid) and required to present a seminar to the other trainees in the group about his/her assigned disruptive technology. Every trainee was required to attend all seminars. The trainees were then required to produce an extended piece of writing about their assigned disruptive technology (1000 words) plus a shorter summary piece (600 words) on the other

---

[1] In England the term 'trainee teacher' is used interchangeably with 'student teacher', both terms having a similar meaning to 'preservice teacher'.

disruptive technologies. In addition, each trainee had to suggest how they could teach their disruptive technology topic in a design and technology lesson, which would provide opportunities for embedding thinking skills, creativity and problem solving skills (1500 words) with regard to his/her assigned disruptive technology.

This paper will limit itself to a consideration of the extended pieces of writing that six trainees undertook about their assigned disruptive technologies.

Data collection and analysis

The six selected trainees considered the following disruptive technologies:

- Additive Manufacture
- Artificial Intelligence
- Big Data
- Neurotechnology
- Programmable Matter
- Synthetic Biology

Each trainee gave permission for their response to the assignment to be scrutinised for the purposes of this paper. Each response was scrutinised with regard to the following questions.

1. Did the response indicate that the trainee understood the nature of the disruptive technology?
2. Did the response indicate that the trainee appreciated the breadth of application of the disruptive technology?
3. Did the response indicate that the trainee has identified arenas of activity in which the technology was likely to be disruptive?
4. Did the response indicate that the trainee has identified the nature of the disruption created by the technology?

The results of the scrutiny are shown in Table 2

Table 2 Analysis of trainee's assignments

	Understanding the nature of the technology	Appreciating the breadth of application	Identifying arenas of activity	Identifying the nature of the disruption
Additive Manufacture	A clear understanding is shown	Some appreciation of breadth is shown although the printing of function as opposed to structure is not considered	There is some identification of disruption	There is little consideration of the nature of disruption
Artificial Intelligence	A clear understanding is shown	A clear appreciation is shown	Clear identification of arenas of activity	The nature of disruption considered existential threat
Big Data	A clear understanding is shown	A clear appreciation is shown	Clear identification of arenas of activity	This is considered in moderate detail
Neuro-technology	A clear understanding is shown	A clear appreciation is shown	Two main arenas of activity were identified but not discussed in terms of disruption as such	This was not considered
Programmable Matter	A clear understanding is shown	A clear appreciation is shown	Clear identification of arenas of activity	This is considered only to a limited extent
Synthetic Biology	A clear understanding is shown	A clear appreciation is shown	Clear identification of arenas of activity	This is considered only to a limited extent

Discussion

To what extent does an introduction to disruptive technologies help the trainee teachers learn about disruptive technologies, their applications and impact?. It must be acknowledged that the task set to the trainees is demanding, requiring them to acquire knowledge and understanding of topics that were new to them and to view these from the perspective of disruption which was again a new topic as far as they were concerned. It must also be acknowledged that the imposed word limit does constrain the trainees' ability to be expansive in showing their grasp on the topics they were given. The trainees were given their topic at the start of the module, each was timetabled to present their work starting four weeks later. Between this and the first trainee-led presentation other lecturers gave seminars about other new technologies, not necessarily disruptive, modelling

how they could present their topic. Planning and delivering a seminar that lasted between 30 and 45 minutes, on an unfamiliar topic for presentation to their peers presented several challenges for the trainees. Additionally, the concept of disruptive technologies as a component of the design & technology curriculum challenged their preconceptions. Their prior experiences involved handling materials and components, and designing and making solutions, none of which was a possibility with most of the disruptive technologies; possible exceptions including additive manufacturing, robotics and the Internet of Things. In the light of this, it is encouraging to see that all the trainees were able to find out about the technologies they researched, both in respect of the nature of the technology and its main applications.

Whether the idea of disruption (as defined within the Project) is sufficient to enable the trainees to explore the disruptive potential of new technologies? Most trainees were able to identify at least some areas where the technology might be disruptive but they were less successful in considering the extent to which a technology might be disruptive. None of the trainees explicitly used the McKinsey criteria for disruption (Manyika et al 2013) in considering the impact of the technology on society or used scenario building to explore possible futures involving the technology. However, they all discussed ethical issues with regard to the deployment of the technologies. This is not surprising as we might expect design & technology trainee teachers to be adept in understanding technologies and their applications, but the ideas surrounding 'disruption' in the sense that we have used the word, leaning heavily on the McKinsey 'features of disruption' (Manyika et al 2013), are probably novel and will take some time to absorb. A useful follow-up to this study would be to track the trainees through their in-school placements and in the first years of full time teaching to find out if they are teaching about disruptive technologies and if so how and with what success. It would also be useful to undertake parallel research with serving teachers to establish whether they, like the trainees, have little difficulty in grasping the nature of the disruptive technologies and possible applications, but need more support in dealing with the ideas surrounding disruption.

This brings us to an interesting point with regard to the place of such technologies in the school curriculum. The centrality of values to designing and the potential of school design & technology as a context for teaching pupils about values is a recurring theme in the literature (e.g. Layton 1995, Middleton 2005, Barlex 2007, McLaren 2015). In teaching young people about the technologies and their impact on society, it is likely that they will develop a value position with regard to that impact. They may even come to school with value positions already in place that design & technology lessons may either reinforce or challenge. For example, does the technology under consideration lead to benefits and if so for whom? Does it lead to others being disadvantaged? And, more profoundly, whatever the winners versus losers situations that arise, should we be deploying these technologies at all given that, in the case of at least some of these technologies (for example Artificial Intelligence and Synthetic Biology), some argue that humans are 'messing with nature' and going beyond our remit as stewards of the world (see Macnaghten et al 2010 with respect to cultural narratives influencing views on technology). Stevens (in press) writing about the teaching of bioethics raises the interesting question of assessing students' responses to value positions suggesting that they should not be judged by comparison with a given, and perhaps preferred value position of the assessor, but whether the position is well supported or not by the arguments provided by the students.

Summary
This paper has set the scene for a consideration of disruptive technologies to be investigated in the secondary school design & technology curriculum. It has described the responses of trainee teachers to tasks requiring them to learn about such technologies and comment on their impact on society. The responses indicated that the trainees had grasped some essentials of the technologies, could identify some ethical concerns with regard to their deployment but were less

secure in considering their disruptive nature. The discussion considered the professional development teachers in post might need and identified the issue of assessing school students' value positions with regard to the deployment of disruptive technologies.

References

Barlex, D. (2007) Justifying design & technology. In Barlex, D. (Ed.), *Design & technology for the next generation* Whitchurch, England: Cliffeco

Barlex, D. (2012). The Young Foresight Project A UK Initiative in design creativity involving mentors from industry. In B. France & V. Compton (Eds.), *Bringing communities together: Connecting learners with scientists or technologists* (pp. 113-126). Rotterdam, The Netherlands: Sense

Barlex, D., Givens, N. & Steeg, T. (2015). Thinking about disruptive technologies. In Gwyneth Owen-Jackson (Ed.), *Learning to Teach Design and Technology in the Secondary School* (pp.303-322). 3rd edition Oxford, England: Routledge

Barlex, D., Givens, N. & Steeg, T. (2016) The Disruptive Technologies Project available at https://dandtfordandt.wordpress.com/projects/disruptive-technologies/

Birtchell, T., Urry, J., Cook, C. & Curry A. (2013) Freight Miles Impacts of 3D Printing on Transport and Society ESRC Project ES/J007455/1. Retrieved June 11 2016 from http://eprints.lancs.ac.uk/66198/1/Freight__Miles_Report.pdf

Department for Education (2013) *Design and technology programmes of study: key stage 3*. London, England: Department for Education

Department for Education (2015*) Design and technology GCSE subject Content*. London, England: Department for Education

Department for Education and Skills (2004) *Key Stage 3 National Strategy Foundation Subjects Design & Technology: Framework and training materials,* London, England: DfES

Gartner (2015) Gartner Hype Cycle. Retrieved June 11 2016 from http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

Layton, D. (1995) 'Constructing and Re-constructing School technology in England and Wales' *International Journal of technology and Design Education* 5:89-118

Macnaghten, P., Davies, S. & Kearnes, M. (2010) Narrative and Public Engagement: Some findings from the DEEPEN project. In René von Schomberg and Sarah Davies (Eds) *Understanding Public Debates on Nanotechnologies Options for Framing Public Policy* Luxemberg: European Union

Manyika, J. et al (2013) *Disruptive technologies: Advances that will transform life, business, and the global economy* McKinsey Global Institute. Retrieved June 11 2016 from http://www.mckinsey.com/insights/business_technology/disruptive_technologies

McArthur, E. (2015) Resources developed by the Ellen McArthur Foundation can be found at http://www.ellenmacarthurfoundation.org/schools

McLaren S. V. (2015). Developing Values. In Gwyneth Owen-Jackson (Ed.), *Learning to teach design and technology in the secondary school* (pp. 287-302). 3rd edition Oxford, England: Routledge

Middleton, H. (2005) 'Creative Thinking, Values and Design and Technology Education' *International Journal of Technology and Design Education 15:61–71*

Observer (2015) Retrieved June, 11 2016 from http://observer.com/2015/08/stephen-hawking-elon-musk-and-bill-gates-warn-about-artificial-intelligence/ but also http://www.bbc.com/news/technology-35082344 for a more positive view

Stephens, D. (in press) Teaching Bioethics: The intersection of values and the applications that advances in technology make possible. In Barlex, D. & Williams, P. John (Eds.), *Enhancing technology education Helping teachers develop research-informed practice*. Singapore: Springer

Willets, D. (2013) *Eight Great Technologies*, London, England: Policy Exchange

Primary Design and Technology: Perceptions and practice

Dawne Bell[1], Mike Martin[2], David Wooff[1], Matt McLain[2],
[1] *Edge Hill University, St Helens Road, Ormskirk, Lancashire, L39 4QP United Kingdom*
[2] *Liverpool John Moore's University, IM Marsh Campus, Aigburth, Liverpool, L17 6DB, United Kingdom*
belld@edgehill.ac.uk

Abstract:

Design and technology is recognised in many countries as a valuable subject in developing children's knowledge and skills about materials, as well as decision making through creative design processes. As such it makes a unique contribution to a child's general education and provides a foundation for future work with all forms of technology across professional and personal lives.

However in England and Wales, the countries where the subject was first conceived, following educational policy change and the subject's exclusion from the English Baccalaureate, design and technology is persistently required to justify its place within the curriculum (DATA 2011). Amid concerns that primary teachers are insufficiently trained to teach design and technology (DATA 2015) and set within the context of primary education and building upon findings from earlier research (Bell et al. 2016), which sought to establish the range of design and technology work currently being undertaken in primary schools, this paper presents next phase research findings.

Constructivist grounded theory (Charmaz 2006) is the adopted method, and drawing upon empirically grounded data, this paper explores the attitudes and perceptions of primary school teachers.

Participants were encouraged to reflect upon their own experience, to establish if they believe they received sufficient subject specific training. Work then explores their perceptions, to determine if they perceive that their personal subject knowledge has a direct impact upon the breadth and quality of work undertaken. Emergent findings are discussed in relation to the value placed upon of design and technology, and findings suggest that curriculum delivery is compromised where teacher confidence is low.

Future work will seek to investigate teacher perceptions further, aiming to explore the correlation between teacher's personal subject knowledge and the quality and creativity of work undertaken in design and technology, with a particular focus upon how knowledge is constructed and understanding developed.

Introduction:

There is little empirical evidence available that makes clear primary school teachers' beliefs and perceptions in relation to the subject of Design and Technology in England and Wales. In light of recent curriculum change (DfE 2013a) it is important to investigate the impact that policy change has had on classroom practice. Set within the context of primary age phase education in England and Wales (Ages 5 – 11 years old), amid concerns that primary school teachers are insufficiently trained to teach design and technology (DATA 2015; Benson and Lunt 2011), and anecdotally limited formal opportunities for teachers to undertake subject specific professional development. This paper presents findings from research which initially sought to establish the range of design and technology work currently undertaken in such settings, before exploring the perceptions and practice of primary school teachers, and primary teachers in training, to establish if they perceive that their personal subject knowledge has a direct impact upon the depth, breadth and quality of work they undertake in design and technology.

The evolution of the primary design and technology curriculum:
Design and technology is a valuable subject (Barnes et al. 2002; Middleton 2005; Barlex 2007; DATA
2011; Owen-Jackson 2013; Hardy 2015) which makes a unique contribution to a child's education,
yet in the country where the amalgamated 'new' subject of design and technology was arguably
conceived (DCSF 1989), it faces a constant challenge, battling to position itself as a subject of
worth within the curriculum within both the primary and secondary age phase.

After almost three decades of curriculum reform (DfE 2013a; 2013b) design and technology has been
persistently marginalised (Bell 2016; Green 2014). Within primary education in England and
Wales a child's entitlement to receive design and technology's remains, whilst the quality
assurance mechanisms have been removed. Subject specificity is no longer reported as a discrete
outcome under the latest iteration of the inspection framework (Ofsted 2015), indeed it is
sometime since separate subject reporting was a feature of educational quality assurance in
England and Wales (Elliott 2012). Quality assurance of school phase education in England and
Wales is directed by the Department for Education (DfE) and enacted by the Office for Standards
in Education, Children's Services and Skills (OfSted). Thus there is no centralised mechanism that
reports findings which relate to the quality of primary age phase design and technology provision.

Methodological approach and research methods:
The approach adopted for this study aligns with constructivist grounded theory (Charmaz, 2006).
Underpinned by an interpretivist ontology, this approach adopts an abductive methodology,
which combines both inductive and deductive theory generating procedures. The resultant being
that theoretical concepts are constructed, rather than being 'discovered', with reasoning being
undertaken after analysis of the data. In this study both qualitative and quantitative research
methods were utilised, so it could be said that a mixed methods (Cohen et al. 2013) approach was
an underpinning factor in the research design. Data was collected using a combination of
multimodal questioning, an online survey and semi-structured interviews.

The research sample:
Convenience sampling (Cohen et al. 2013) was utilised for participant selection during the initial
research phases which engaged two hundred and fifty one participants (n=251). During this initial
phase of the study, participants were either primary age phase qualified serving teachers, or
student teachers, (both undergraduate and postgraduate), currently training to teach within
primary age phase settings located across England and Wales.

Subsequent research phases adopted purposeful and finally theoretical sampling techniques, and
engaged 18 participants, who were all primary age phase qualified teachers. Participants were
drawn from a wide range of educational settings, and selected to ensure diversity of experience,
personal attributes and demographic characteristics.

Procedures for data analysis:
In line with this study's chosen methodological approach concurrent data generation and analysis
occurred, with emergent outcomes from each research phase informing subsequent ones.
Utilising methods advocated by Bryant and Charmaz (2007) and Charmaz (2014) care was taken to
ask exploratory, rather than interrogative questions, with coding analysis procedures advocated
by Glaser (1992) and Charmaz (2014) being employed. Data gathering occurred until saturation of
the theoretical conceptual categories was deemed to have happened by response replication.

Ethical considerations: Prior to
participant engagement, the aims were explained to all participants and informed consent

obtained. Interviews took place in a neutral setting, at a time convenient to the participants, within the ethical guidance framework as described by the British Educational Research Association (BERA 2011). Semi-structured interviews utilised procedures advocated by Bowden and Green (2005) and Charmaz (2006, 2014), and were recorded and transcribed verbatim, with care taken to accurately record responses in order to avoid misrepresenting the false attribution of meaning to comments and phrases. This ensured researcher neutrality prevailed and the data was not tainted or influenced by the pre-conceived ideas of the research team.

Presentation of findings:

Initial research sought to establish the range of design and technology work currently being undertaken in primary age phase settings. This phase engaged the full research cohort of participants (n=251), who were either qualified teachers or students training to become primary age phase teachers within England and Wales.

Using multimodal data collection methods at this a stage of the study participants were asked;

1. What is being taught?

This question sought to establish the breadth of work currently being undertaken within primary schools in England and Wales by asking participants what is actually being taught in the classroom, as such the responses for both groups of participants were combined. Figure 1 illustrates the range of projects identified by the study as currently being undertaken. As this was an open ended question, the definition of what *is* a primary age phase design and technology project was open to participant interpretation, and yielded the following responses;
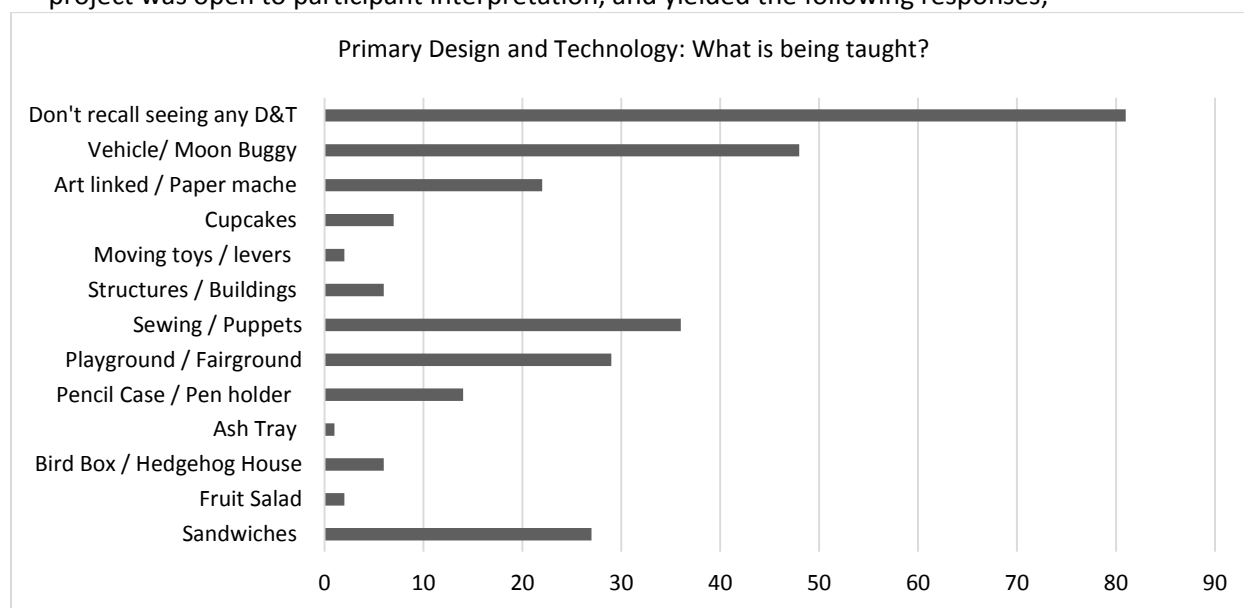
Figure 1: Primary design and technology; what is being taught?

Summary and discussion of initial research findings:

Outcomes of analysis from findings gleaned during this initial phase informed the development and direction of subsequent phases. First phase findings indicate, as could be predicted, that there is a range of activity perceived to be design and technology currently being undertaken in primary schools across England and Wales. However of the 251 participants 32.2% (n=81) reported that no design and technology activity was undertaken within their educational setting.

This statistic could be attributed solely to student teacher responses, as they may not have witnessed any design and technology activity within their setting whilst undertaking their professional placement. This is not to say that schools in which these students were placed were failing to provide the statutory design and technology curriculum entitlement for their students, rather the very short time schools spend on primary design and technology have not been coincidental to the timing of the individual students placement. However this in itself raises concerns in relation

to the number of students currently training to teach, who may not have the opportunity to gain practical experience of subject delivery during their training in a school setting.

This is something which has not gone un-noticed. In expert witness testimony to a cross party education select committee, the assistant chief executive of the national subject association, The Design and Technology Association (DATA) drew policy makers' attention to the statistic that primary age phase teachers in training could actually be expected to deliver primary design and technology with as little as four hours subject knowledge input as part of their teacher training course. (Mitchell 2016).

In terms of the work undertaken 8.8% (n=22) of participants cited art linked/ papier-mâché work as some of the projects which they observed taking place. Within the primary Key Stage 1 and Key Stage 2 national curriculum (DfE 2013a) this would not usually be considered to fulfil the design and technology requirement for subject knowledge. Popular work identified as being undertaken in schools included food related tasks [sandwiches, cupcakes and fruit salad] which when combined accounted for 14.3% (n=36) of responses and the creation of vehicles / moon buggy's which accounted for 19.1% (n=48) of responses.

Underrepresented activity within the confines of the curriculum (DfE 2013a; 2013b) included those areas which could be considered to be more technical in nature with project work including the delivery of levers and structures accounting for only 3.1% (n=8) of responses.

Identification of Phase 2 Participants:

In line with the study's methodological approach, findings from analysis of the first data phase informed the direction of the next phase. Analysis was supported by the use of theoretical memos, and work focused on how aspects of the study related to participants experiences of their practice, and represented some of the challenges found within participants' working environments.

Data collection methods included multimodal survey techniques, with follow up interviews. This phase focused on 18 participants, all of whom were qualified, serving primary age phase teachers, rather than teachers in training.

Participants were selected in accordance with Geertz's (1973) methodology for determining a purposeful and theoretical sample from an identified cohort. It was anticipated that this would yield the most representative sample of participants who in turn could provide a rich and varied account of their experience (ibid).
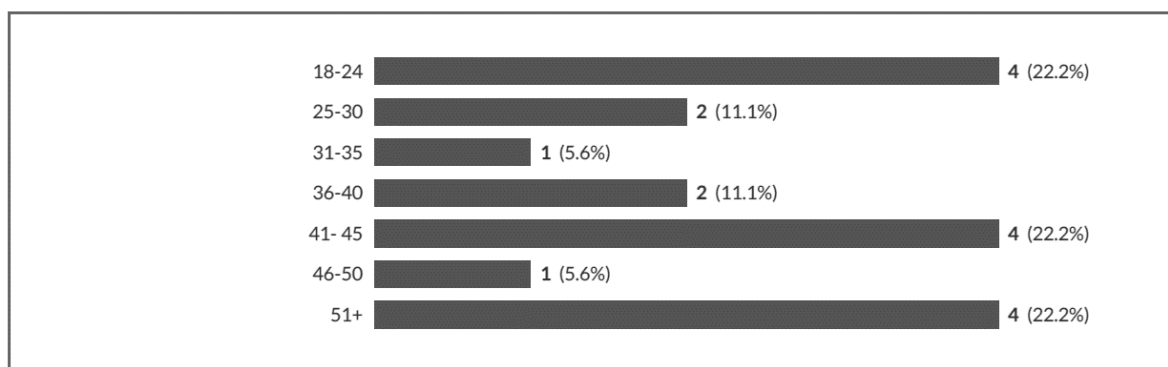
Figure 2: Age demographic of the second phase participant cohort.
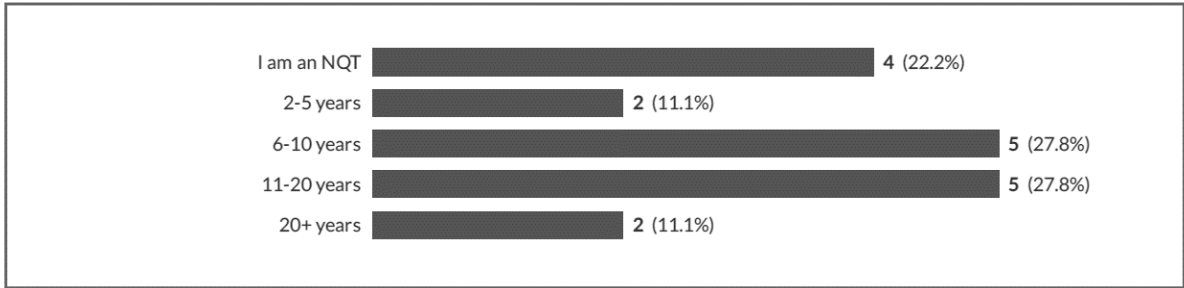
Note: A Newly Qualified Teacher (NQT) is someone in their probationary year following the successful completion of their teacher training course.

Figure 3: Length of service of those in the secondary phase cohort.

Findings from the second phase:
During this second phase participants were asked a series of questions relating to their experience of design and technology curriculum arrangements in their own context, aspects of; planning, preparation, delivery and confidence were all investigated. Initially the study sought to establish *'How often / how many hours is design and technology taught within your school / setting?'* participants reported the following responses in a pre-coded matrix of options:
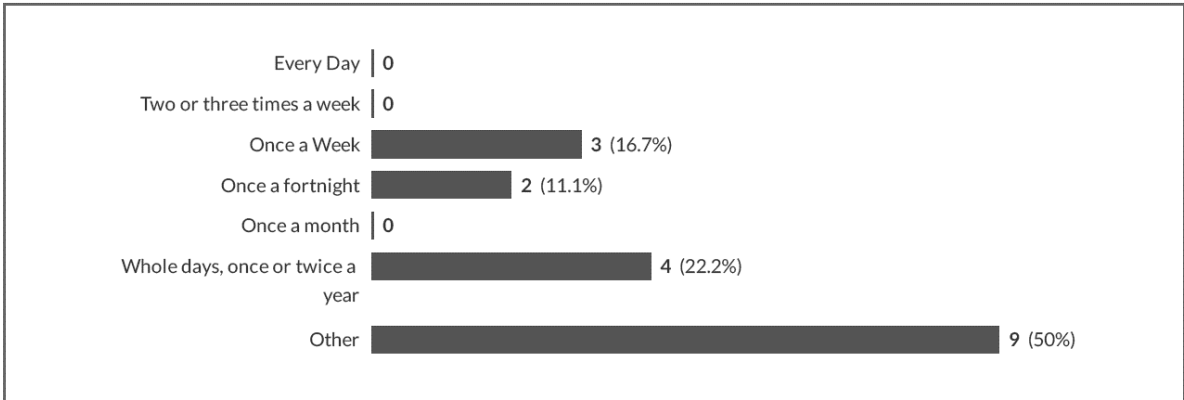
Figure 4: Frequency of design and technology teaching

Following this, the next question sought to establish if the participant perceived they had received any specific training, or they held any specialist qualification, in order to enable them to plan for and deliver design and technology:
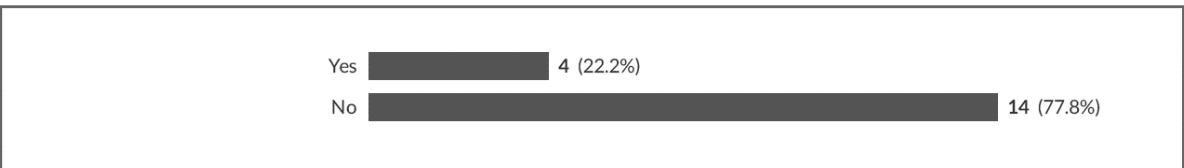
Figure 5: Participants experiences of their own design and technology training and qualification

This was followed with a question designed to explore participant's confidence and readiness for the delivery of design and technology in the classroom.
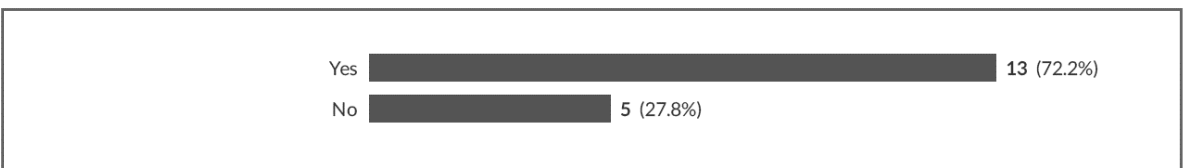
Figure 6: Participant confidence in their own ability to deliver design and technology.

Given that the study has already sought to investigate training and confidence, the research team felt it important to also look at the levels of resourcing and support for teachers of design and technology in the primary age phase classroom. A pre-coded set of alternatives were open to respondents, however, they were free to select as many options as they desired. Consequently the 18 participants provided a cumulative total of 33 responses, making the response rate to the question to be 1.83 responses per participant.
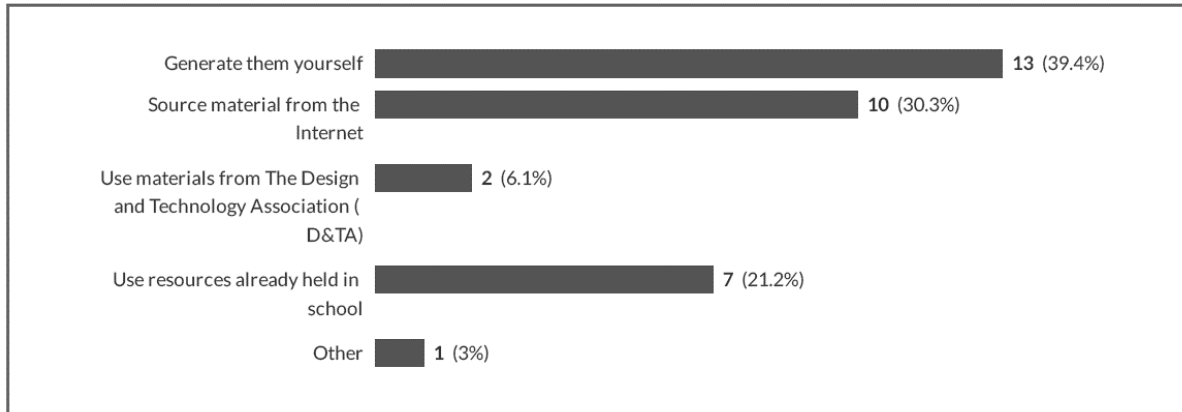
Figure 7: Data showing sources participants used to source support materials for their design and technology lessons.

A follow up question was asked about the setting in which the participants worked, and it sought to establish if any participant or their school held membership of DATA. No one indicated that either they or their school (100%, n=18) were affiliated to DATA.

To conclude participants were asked to contribute any other relevant information not previously covered. 38.9% (n=7) of participants responded to with the majority highlighting limited curriculum time and the impact of financial restrictions on both equipment and resources:

It's a real shame to think that 20 years ago, my classroom had a workbench and simple tools. There is no such facility in any primary school anymore.
Participant Four

Schools do D&T as a treat at the end of a unit of work if applicable and it is not respected as a standalone subject in the curriculum.
Participant Eighteen

Analysis of second phase findings:
Analysis of the second phase findings revealed that in the majority of primary age phase settings (72.2%, n=13) design and technology activity took place over the space of whole days for no more one or two times per year, with only 16.6% (n=3) of participants indicating that design and technology was taught within their scheduled school curriculum once a week. Where participants had cited delivery during blocks of time, further analysis illuminated some creative approaches to content delivery, frequently linked to whole school cross-curricular project and topic work.

The two questions which looked at training and qualification when compared to the one that explored teacher confidence show a direct correlation. The numbers of participants who identified that they had no qualification or training (77.8% n=14, Figure 5) was reflected in a seemingly linked lack of confidence in their own ability to deliver the subject (72.2% n=13, Figure 6). Interestingly, one participant self-determines that they have the confidence to deliver the subject effectively but they have no training or qualification to underpin this.

In considering the planning and preparation of design and technology lessons, one participant said they not generate or use resources. The majority of participants (72.2% n=13, Figure 7) said they either generated their own resources, or acquired resources from the Internet (55.6% n=10,

Figure 7). As previously mentioned, this question allowed users to record multiple options, so collectively, from all of those selected this represents 69.7% (n=23) of responses against a total of 33.

Statistical information acquired from DATA (Adam 2015) indicates that the subject association has supplied 1,382 design and technology primary project resource packs in support of the primary age phase curriculum. It should be noted though, that these are only available to purchase and there is no cost free option. As previously highlighted, in this study no one indicated that their school held a subject association membership. However, 11.1% (n=2) of participant's indicated they did utilise some DATA primary resources which could mean that they borrowed resources or obtained them whilst working at a previous school.

In January 2015 there were 24,317 primary schools and academies in England (DfE 2015), and 1,330 in Wales (Welsh Government 2015) which would account suggest only 5.4% of primary schools have purchased the DATA resources to support the delivery of design and technology in their schools.

Discussion and conclusion:

Findings from this study make clear that there are pockets of excellence in the delivery of primary phase design and technology education, however analysis of findings suggests that in the majority of instances a restricted primary design and technology curriculum is in operation, if it exists at all.

Nascent patterns from the data would suggest that in addition to the lack of training to deliver design and technology aligned to teacher self-confidence and belief in their intrinsic ability to deliver the subject. This confidence level could be impacted by the non-uniform method of delivery in schools, and consequently the infrequency of regular lesson planning, preparation and delivery will be a contributory factor in the quality of design and technology work undertaken.

It is also worth drawing attention to the clear correlation between participants' responses from the second phase of the study to determine if they perceived that they had received any specific training, or held a qualification to support them in the delivery of design and technology. The number of respondents who commented positively here saying that they had undertaken this training (22.2%, n=4, Figure 5) almost identically mirrors the number of participants who said they felt confident to plan and teach design and technology (27.8%, n=5, Figure 6) which would suggest that the training they undertook was valued.

A worrying outcome from the study is that from the original 251 participants engaged in the initial phase 32.2% (n=81, Figure 1) indicated that they did not recall seeing any projects they would consider to fall within the design and technology curriculum. This raises the question do respondents have the ability to determine exactly what a design and technology project is? If the data from phase 2 showing those who have not received any subject specific training (22.2%, n=4, Figure 5) is considered alongside this it is reasonable to assert that a number of participants in this study have neither knowledge, confidence or training to determine when a project aligns with the design and technology curriculum.

The latest national curriculum revision (DfE 2013a) goes someway to trying to develop a suitable and fitting curriculum for pupils to undertake suitable classroom activities in order that they can effectively develop 21st Century Skills for their future studies and ultimately their intended careers. However, having concluded this initial study it shows a worrying landscape of disparate provision across the primary sector, championed by enthusiastic but ill equipped teachers, doing their best within the circumstances they find themselves; struggling against budgetary constraints and limiting facilities, in addition to the issues of training and teacher confidence

It is clear that further work should be undertaken in this area. Of interest is the assertion that many non-subject specialist teachers are engaged in specialist subject delivery (Mitchell 2016) which undoubtedly will be having a significant impact on the quality of design and technology teaching in the primary classroom. The research team involved in this initial study is already seeking to investigate further teacher perceptions, in order to explore the correlation between teacher's personal pedagogical subject knowledge and the quality of application in practice.

References:

Adam, W. (2015). DATA Educational resources, private email correspondence. October 2015.

Barlex. D. (Ed.) (2007), Design and Technology: For the Next Generation, England, Cliffeco Communications, 2007.

Barnes, B., Sayers, S., & Morley, J. (2002). Issues in design and technology teaching Psychology Press.

Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. International Journal of Technology and Design Education, 26(1), 61-79. doi:10.1007/s10798-015-9300-9.

Bell, D., Wooff, D., Wright, S., Martin. M. and McLain, M. (2016). Primary design and technology: what do primary teachers do? Annual Conference for Research in Education (ACRE); Values in Education, Edge Hill University.

Benson, C. and Lunt, J. (2011). International Handbook of Primary Technology Education: Reviewing the Past Twenty Years. Springer Science & Business Media.

British Educational Research Association (BERA). (2011). Ethical guidelines for educational research. http://content.yudu.com/Library/A2xnp5/Bera/resources/index.htm?referrerUrl=http://free.yudu.com/item/details/2023387/Bera Accessed 10th May 2016.

Bowden, J. A., & Green, P. (Eds.). (2005). Doing developmental phenomenography. Melbourne: RMIT University Press.

Bryant, A. and Charmaz, K., (2007). The Sage handbook of grounded theory. Sage.

Charmaz, K. (2006). Constructing grounded theory: A practical guide through qualitative analysis (Introducing Qualitative Methods Series).

Charmaz, K. (2014). Constructing grounded theory. Sage.

Cohen, L., Manion, L., & Morrison, K. (2013). *Research methods in education* Routledge.

Design And Technology Association (DATA) (2011). We Believe in D&T Campaign, http://www.data.org.uk/generaldocs/Manifesto/data_manifesto.pdf Accessed 9th April 2016.

Design And Technology Association (DATA) (2015). What are the Issues? Critical shortage of qualified D&T teachers, https://www.data.org.uk/campaign/what-are-the-issues Accessed 10th May 2016.

Department for Education. (DfE) (2013a). The national curriculum in England: Key stages 1 and 2 framework document. September 2013. Primary https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/239041/PRIMARY_national_curriculum_-_Design_and_technology.pdf Accessed 10th May 2016.

Department for Education. (DfE) (2013b). The national curriculum in England: Key stages 1 and 2 framework document. September 2013. Primary https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/425601/PRIMARY_national_curriculum.pdf Accessed 9th May 2016.

Department for Education. (DfE) (2015). Statistical First Release; Schools, pupils and their characteristics: January 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/433680/SFR16_2015_Main_Text.pdf Accessed 18th May 2016.

Department for Education. (DfE) (2016). Primary school accountability in 2016. A technical guide for primary maintained schools, academies and free schools. January 2016. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/496158/Primary_school_accountability_in_2016.pdf Accessed 10th May 2016.

Department For Children, Schools And Families (DCSF) 1989. *The National Curriculum*, Pub: Her Majesty's Stationary Office, London, England.

Elliott, A. (2012). Twenty years inspecting English schools – Ofsted 1992-2012. http://risetrust.org.uk/pdfs/Review_Ofsted.pdf Accessed 8th April 2016.

Geertz, C. (1973). Thick Description: Toward an Interpretation Theory of Culture in; The Interpretation of Cultures: Selected Essays, New York, Basics Books Inc.

Glaser, B. (1992). Basics of Grounded Theory Analysis; emerging vs. forcing. Mill Valley, CA: The Sociology Press.

Green, R. (2014). In J. Burns (Ed). Teachers fear for the future of design and technology. http://www.bbc.co.uk/news/education-30484428 Accessed 11th May 2016.

Hardy, A. (2015). What's D&T for? gathering and comparing the values of design and technology academics and trainee teachers. *Design and Technology Education: An International Journal*, 20(2).

Middleton, H. (2005). Creative thinking, values and design and technology education. International Journal of Technology and Design Education, 15(1), 61-71.

Office for Standards in Education, Children's Services and Skills (Ofsted) (2015). School inspection handbook; Handbook for inspecting schools in England under section 5 of the Education Act 2005. https://www.gov.uk/government/publications/school-inspection-handbook-from-september-2015 Accessed 8th April 2016.

Owen-Jackson, G. (2013). Debates in design and technology education, Routledge.

Mitchell, A (2016) Commons Education Select Committee Supply of Teachers Inquiry, https://www.data.org.uk/news/commons-education-select-committee-supply-of-teachers-inquiry/ Accessed 10th June 2016.

Welsh Government (2015) Circular SDR110/2015 First Release School Census Results 2015, http://gov.wales/docs/statistics/2015/150723-school-census-results-2015-en.pdf Accessed 10th June 2016.

"I can't see how to do it": Left handed pupils – are their needs being met in design and technology in primary settings?

Clare Benson and Ruth Bond
Birmingham City University, UK
clare.benson@bcu.ac.uk

Abstract

There has been little research into the way in which left handed primary pupils are supported, particularly with their practical work, in design and technology (D&T) and other practical subjects such as art and physical education. Is it necessary to identify these children and ensure that they are given appropriate support both with equipment and with how to approach tasks in a left handed way or do they just adapt to 'their way'? Clark (1974) clearly stated that left handers should be given appropriate support and treat cases on an individual basis to ensure that all children have an equal opportunity to succeed and fulfil their potential. McManus (2002) and Pratt Smith (2007) both identified the challenges met by left handers when their special needs were left unsupported and Paul's findings(1990) relating to textile work also identified the lack of self esteem for these children when they could not achieve the results they wanted.

Having identified a number of left handed children that seemed to be having problems in D&T, particularly in practical work, case study research into the perceived problems took place in a junior school (pupils aged 7-11 years). Further research took place during teacher courses into the way in which these teachers approached this issue. Research methods in school included lesson observations, teacher interviews and questionnaires; teachers on courses undertook questionnaires and then took part in short discussions in small groups, with findings fed back to the whole group. Data was analysed and findings were identified, most of which complimented each other. There is a definite need for an organised approach to support left handed pupils enabling them to achieve their potential. Implications for developing appropriate practice are identified and the need for future research identified.

Key words

left handed pupils, primary design and technology (D&T), practical subjects, self esteem, laterality

Introduction – setting the context

The research into left handed pupils and their attainment in practical subjects, in particular design and technology (D&T), arose as a result of a school's identification of possible problems and it became a focus for an unpublished MA Ed research project. Follow up research took place with groups of primary teachers on D&T development in order to ascertain whether the case study conclusions could be supported in a wider context. The case study school is in the outer suburbs of Birmingham, is a junior school (pupils aged 7-11 years) and has a three form entry (approximately 370 pupils). The school staff has been well supported in D&T with planning, skills and knowledge development and there is a wide range of resources available. However, there was no policy or handbook in relation to left handers and after the research was underway, it was found that 20% of teachers were left handers and 15% of all pupils. As Milson (2008) states "There is a significant gap in teachers' knowledge relating to the left handed pupils" (p.51). There were three groups of primary teachers that took part in the follow up research, all from the West

Midlands, England - a total of 74 teachers. They were all on development courses for primary D&T and the issue of left handers had been included in each course.

Theoretical perspective

Whilst there is a range of authors who have looked at laterality, some of whom have an educational research base, there is a gap when it comes to looking at D&T specifically. However some of the research is useful to examine in relation to D&T and forms a foundation for more focused research. Clark (1974) looked at left handers from a general educational viewpoint and found decisively that they were at a disadvantage from the time of their entry into school. "Other pupils are shown how to place the paper and hold the pen, but the left hander is left to discover these things entirely by himself" (p.41). Many pupils that were interviewed by Clark felt themselves to be inferior, both through interaction with other pupils and with their teachers. Many were encouraged to change hands which had an impact on their emotional well being and speech. 40% of children interviewed were found to stammer or have other speech difficulties. Paul's research (1990) in Manchester schools supported previous findings and stresses the need for pupils to be provided with equal opportunities and equal access to the curriculum. She identifies specific issues for D&T including the difficulties faced by left handers when teachers demonstrate skills from a right handed perspective. However a positive finding was the better spatial awareness of left handers that was a key skill when carrying out design aspects of D&T. Kelly's work (1996) again supported previous findings. She looked at left handers from the 1940s to the present day, identifying the focus in the 1940s of making children change from left to right at school to the present day when teachers rarely know how many children in the classes are left handers. "Virtual invisibility of left handers is a major problem in schools. Most right handers, including right handed teachers fail to realise how different the world is for the left handed." (p. 21). The issue of self esteem needs to be tackled immediately as "all pupils are unique and that their uniqueness needs to be addressed in a non judgemental fashion". (p.89)

Following the launch of a video ' Left handed children' (Stewart 2012) Anthea Millett (Chief Executive, the Teacher Training Agency) admitted that there was a gap in the provision of guidance for teaching left handers in Teacher Training and supported the distribution of the video to all Teacher Training Institutions. However there was no evaluation of the initiative and so no data available to see what effect the video might have had. An article in the Times Educational Supplement (Julius 1999) focused on the fact that there was no data on left handers held by the Department for Education and Employment (DfEE) but it was believed that in a class of 30 children 5 would be left handers. Again the article highlighted the low esteem of left handers and how this could affect their basic creative skills, so important in D&T. The left handers found it harder to use inappropriate equipment and the D&T achievements improved when given hand tools designed for them – even something as basic as a left handed ruler. McManus (2002) focused on laterality from a psychological point of view and found that there was a definite stigma attached to being left handed which started in schools. He found that left handers were badly catered for in terms of specialist equipment that they might need. From the 27 London schools that he surveyed, none of the schools knew how many left handed children were on roll, although they did have databases for other groups such as those with special educational needs and from ethnic minority groups. The only specialist equipment that was identified was left handed scissors. He found that it took the children longer to complete tasks using right handed items, leading to children being labelled as 'clumsy' or 'slow'. Pratt Smith (2007) mirrors these findings and supported the idea of low self esteem. "The need to fit in combined with past bad treatment of left handers means left handed pupils find it difficult to admit to needs that might make them different to other pupils". (p. 73)

From the review of the literature, there is clear evidence that the issue of left handers needs to be urgently addressed. In particular for D&T, the issue of low self esteem could certainly act against a

child's creativity and the ability to create and produce a quality product affected by the lack of appropriate tools and equipment.

Methodology

A decision was made to use a case study approach for the research in school. Both Denscombe (2014) and Cohen et al (2007) identify that advantages of this method include being able to gain detailed data that might be overlooked in larger scale research, to provide actionable strategies, and to be undertaken by a single researcher. It was felt that by studying a group of left handed pupils as a small cross section of the school community more valid and quality data would be gained rather than identifying several groups of individuals, both right and left handers from a wide range of ages and ability, where the focus on left handers would be diluted. It was not the intention to make comparisons between right and left handers but to gain specific information about one group of pupils. The research is structured and was obviously undertaken in a natural setting. As the school based researcher was known to the whole school community the effect of bias was identified from the start and steps were taken to overcome problems as they were perceived.

Data collection methods were considered and evaluated and three methods selected – classroom observations, semi structured interviews for pupils and staff and a questionnaire. It was felt that these would give the richest and detailed data and could be used to cross reference findings. Classroom observations were undertaken in each year group (pupils aged 7, 8, 9 and 10 years) focusing on the left handers. There were approximately 5 pupils in each class of varying abilities in literacy and numeracy and from different social backgrounds. There were parallel classes in each year group and different factors affected the choice of which class to observe in, mainly classes where the researcher was less known to the children. This was to try to counteract the pre conceived ideas that the researcher may have in relation to individual pupils. Cohen et al (2007) observed that the researcher must take into account the effect of the research on the participants – both pupils and staff - and as the researcher was known to all there could be an impact on the behaviour of those involved. The researcher made the decision to start the observations in her own class in order to familiarise herself with completing the schedule and to help allay any fears other staff might have. Both Denscombe (2014) and Gregory (2003) highlight the potential for distress amongst staff as their practice comes under the microscope but as the focus for the research had been a whole school decision and classroom observations were often carried out for a variety of reasons, staff was supportive of the whole project. Observations were carried out every two minutes for approximately an hour and were recorded in an observation diary, with the schedule recording: activity taking place, skills required of left handers, adaptations made, specific support given, and actions of the pupils.

Interviews are useful when researchers are investigating emotions, experiences and feelings (Denscombe 2014) and the researcher wanted to understand how the left handers felt about their experiences. The semi structured nature of the interviews gave them structure but also the flexibility to follow up on the pupils' comments. Interviews were carried out with two groups of left handers – one for 7 and 8 year olds, one for 9 and 10 year olds. Each group had 4 children – 2 with higher abilities in literacy and numeracy and 2 with lower abilities. It was intended that the pupils would feel more confident and not be drowned out when talking in a small group. The interviews were carried out in the library, a familiar school place and one where the environment should feel safe. Care was taken to try and minimise the way in which the researcher might manipulate the process to gain answers that the interviewees feel that the researcher wanted by the use of intonation and body language when asking questions (Bell 2005). Staff interviews were carried out individually at mutually convenient times.

The final data collection method was a questionnaire. A pilot was trialled to try and ensure clarity and an appropriate length. Denscombe (2014) highlighted the negative effect that size can have on giving full answers. The researcher administered the questionnaires and support was given for

any pupils who had difficulties reading the questions. Open ended questions were used in the main to elicit as much information as possible.

The research methods used with the three groups of primary teachers were chosen for pragmatic reasons – to gain as much information about left handed children in their schools in the short time available. They all agreed to fill in the prepared questionnaire after a shortened lunch break, followed by small group discussions (approximately 4 to a group) culminating in a feedback session to the whole group. The researcher made notes, listing each groups' main points and these were then collated. All the teachers involved expressed interest in this issue and were keen to take part in the information gathering.

To ensure ethical considerations were taken into account and to reassure all those taking part that all data gathered was confidential, schools, pupils and teachers would not be named, any data gathered through questionnaires and interviews would not be attributable to any one person. (BERA 2014)

Findings

Overall in the school, left handers accounted for 15% of the pupils (48 in total) and 38% of these pupils (18 in total) were identified as receiving additional support for a range of cognitive issues. Although more subjective in nature, 16% of the study group were found to have behavioural issues (10 pupils) including two who had previously been at a behaviour unit before joining the school. Looking at targets that pupils were expected to reach in literacy, over three quarters of the 48 left handed pupils (12/13) were failing to meet targets in reading and writing with over 12 falling two points behind their expected levels of progress for their age. (Figure 1)
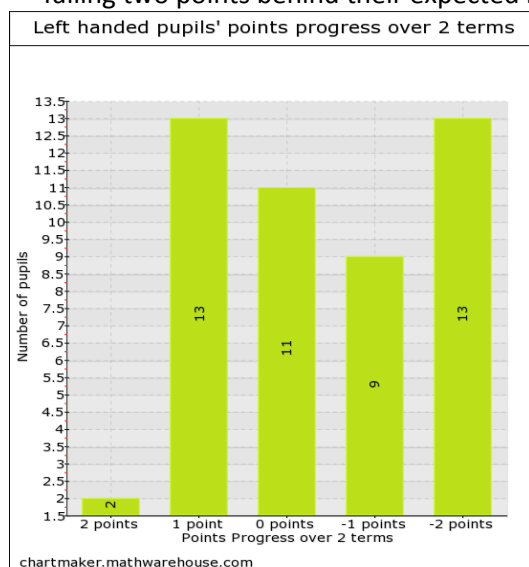
Figure 1

Focusing on the issue of self esteem, it was apparent from the observations that majority of the pupils became frustrated when seeing a demonstration in D&T from a right handed perspective. This led in most cases to the pupils going off task, stopping their work, being disruptive and wandering round the class. One example was that of an 8 year old boy. He was to cut out flowers for a Mother's day card. He did have left handed scissors but they were not cutting. On further investigation, the only adaptation of these particular scissors was that the handles faced inwards but there was no adaptation to the blades. Adult intervention followed and the flowers were cut for him causing him to lose interest and feel that he was failing where most others were succeeding by themselves.

From the questionnaires, 60% of the left handers felt that they did not do well in school in any subject, majority noting that their writing and drawing was always messy and smudged. In the interviews one pupil said: "I don't really do well. I always make a mess with my writing and my teacher has to ask me to read it to her." The pupil had spent some time writing ideas for a plan of action and resources for a D&T project that he might need but felt frustrated that it could not be

read. Another child said that his friend laughed at him when he wrote backwards on a design drawing that he was labelling. These were typical of the comments made both in the questionnaires and the interviews. A large emphasis is placed on handwriting and writing styles in schools because of the national tests for 10/11 year olds and no consideration is given to left handers and any difficulties they may face through no fault of their own. As Kelly (1996) stated: "poor legibility and lack of writing fluency may be factors that keep some lefties from being as successful as their right-handed peers." (p.24) Whilst writing is not a dominant part of D&T, it does play a part and the lack of success must contribute to poor self esteem, making the children feel that they cannot be successful when working on paper, such as drawing and labelling. If they consider themselves to be failing, then that will affect their ability to express their creative ideas.

Focusing on the behavioural issues, from the observations made in D&T it became apparent that frustration and lack of appropriate support led to the majority of cases of poor behaviour in D&T sessions, such as distracting other pupils on the table or around the class. In majority of cases the pupils were left to their own devices and then lost interest or were just told again what to do in the same way leading to frustration and disruptive behaviour when they could not succeed. However from such a small case study it is difficult to draw a definite link to poor behaviour but it is certainly something that needs further research.

From the teacher interviews, it was clear that they felt that they had not been equipped with sufficient knowledge as to how to tackle the issue of left handers in D&T practical work in a sustained and useful way. The two left handed teachers did feel that perhaps the pupils should just adapt as they had done but could see that this might not happen. The main compensation to left handers seemed to be the positioning of known pupils at a table to avoid elbows knocking.

Whilst it is acknowledged that this is a small case study with limited data, nevertheless it does raise questions about left handers in practical D&T sessions and the way in which issues are addressed and support given and it certainly highlights the need for schools to consider this issue.

The findings from the 74 teachers went some way to support the case study findings. 67 of the teachers indicated that they did not know exactly which pupils in their classes were left handed, although 41 of the 67 said they could identify one or two pupils, but were not sure if there were others. None of the teachers knew of a database, policy, handbook or specific support that was offered generally across the school. All the teachers were D&T leaders in their schools and they were asked what specific D&T support they gave the teachers in relation to left handers and what support they gave pupils in their own class. Almost all did buy left handed scissors for practical work but that was the only resource that was supplied. Majority said that the scissors were not labelled in any way and they were not sure what individual teachers did with them in D&T lessons. They had not considered other equipment such a food utensils and saws. They had not provided support material, identified useful websites or given focused sessions for staff development. None remembered having a session on left handers for D&T during their training; that is hardly surprising when for some time D&T has had hours cut within a teacher training course and the time is mainly spent on the nature of D&T and subject knowledge and skills. All the teachers felt that this was an important issue, not just for D&T, and that they would take action on their return to school. Majority felt that it would be something that they would initiate in their own classroom first and then hope to spread it throughout the school. 6 teachers felt that they could go back and straightaway feed ideas to the whole school through staff meetings.

Conclusions and implications for practice

Conclusions
There are 4 main conclusions
- o Left handers and practical work in D&T is an issue that needs to be addressed in schools and researched further.
- o There seems to be a link between behavioural problems and left handers in practical D&T sessions.

99

- Schools need to review appropriate resources for left handers.
- Staff development in schools and in teacher training re left handers and practical work needs to be developed.

Implications for practice
1. The pupils' self esteem and behaviour

Pupils need to feel that they are in a safe and caring environment so that they can feel equal and not at a disadvantage compared to right handed pupils. It was evident that many of the teachers' were unaware of which pupils were left handed and therefore any support that might be needed was not given. As stated by Clark (1974) "It is important that those in charge of children should be aware of left-handers and know how to support and treat cases which they do encounter" (p.18). The correlation between left handed pupils and those with behavioural issues does need to be studied in schools.

2. Provision of appropriate equipment and its appropriate use

It is crucial that all pupils are provided with the correct equipment for their laterality. This includes practical equipment such as scissors and left handed sharpeners. Teachers need to be aware when demonstrating, for example, cutting, sawing, and positioning a blade so it can be seen when cutting takes place.

3. Teacher training

There needs to be a specific input in both initial teacher training and continuing professional development for teachers with regard to left handers. Evidence from the research indicated that this was not an issue that was included in majority of situations and therefore could be perceived to be unimportant.

4. In house policy, handbook and support in relation to D&T

This could include:
- D&T specific
  - providing pupils with appropriate cooking equipment, such as serrated knives with the serrations on the left side, milk pans with lips on the right, peelers with the blade at the top.
  - demonstrating sewing from body to the dominant hand.
  - providing saws with blades on the left, cutting blocks which suit the left-handed style.
  - Scissors
- Linked to D&T
  - ICT- encouraging children to switch the side the mouse is to the keyboard.
  - art-demonstrating skills and techniques using specific tools and equipment.
  - allowing children time and space to complete practical work.
  - seating positions of left-handed children.
  - reading - encouraging them to read from the body to the right side.
  - writing- tilting the paper, avoiding the 'hook', providing left-handed grip pens and pencils.
  - numeracy- how to use a ruler effectively.

Whilst this research has a primary focus, it is equally important that pupils in secondary schools and higher education students are identified and supported. Being left handed does have an impact on a pupil's education from an early age and the quicker this issue is identified and addressed, the more likely all left handers will be able to access the curriculum including D&T in the same way as right handed students.

References

Bell, J. (2005) *Doing Your Research Project: A Guide for First Time Researchers in Education, Health and Social Sciences.* Maidenhead: Open University Press.

British Educational Research Association (BERA) (2014) *Ethical Guidelines for Educational research* . London: BERA.

Clark, M. M (1974) *Teaching Left-Handed Children.* London: Hodder and Stoughton.

Cohen, L., Manion, L. & Morrison, K. (2007) *Research Methods in Education 6th Ed*. London: Routledge.

Denscombe, M. (2014) The *Good Research Guide: for small scale social research 5th ed.* Buckingham: Open University Press.

Gregory, I. (2003) *Ethics in research*. London: Continuum.

Julius, C. (1999) When right is wrong; Left-handedness*. Times Educational Supplement,* 9th April 1999, p.34.

Kelly, E.B. (1996) *Left-Handed Students: A Forgotten Minority.* Indiana: Phi Delta Kappa Educational Foundation.

McManus, C. (2002) *Right Hand, Left Hand.* London: Phoenix Paperback.

Milsom, L. (2008) *Your Left-handed Child.* London: Hamlyn.

Paul, D. (1990) *Living Left-Handed*. London: Bloomsbury.

Pratt-Smith, S. (2007) How a pen is mightier than prejudice. *Times Educational Supplement,* 1st February 2008, p.81.

Stewart, M. (2012) *Teacher Training and the Left-handed Child* http://www.anythinglefthanded.co.uk/teacher-training-left-handed-children.html#sthash.VjHPhm8L.dpbs [accessed 16/05/2016].

http://www.anythingleft-handed.co.uk Video (1998) Coordination skills: left handed children. (accessed 16/05/2016)

Exploring Materials as Subject Content within Technology Education

Eva Björkholm, Susanne Engström and Per Norström
KTH Royal Institute of Technology,
Stockholm, Sweden
evabjork@kth.se; sengstro@kth.se; perno@kth.se

Abstract
Within technology education in compulsory school in Sweden, materials are part of the core contents. What kinds of materials, and which characteristics that should be highlighted is open to interpretation. The study includes three sub-studies: 1/ An analysis of classroom activities during two lessons about materials in primary school, 2/ A Delphi study (Osborne et al. 2003) with experts on materials to gather their thoughts about materials in elementary technology education, and 3/ A review of documents (syllabus, teachers' handbooks). The purpose of this study is to put light on the field of materials as a content area by investigating   what aspects of materials are highlighted in the three contexts. Two teaching sessions were video recorded. The data analysis focused on the objects of teachers and students. Results suggest that the teachers highlight different aspects; one teacher focused on naming the materials and describing what products they are used for, while the other emphasized the materials' properties. Ten experts participated in the first round of the Delphi study. Their responses were coded reflexively and iteratively. Results indicate the following major categories of material-related subject content: groups of materials, properties, creation and refinement, use, development over time, environmental aspects, and modern materials. The syllabus states that young pupils should study materials that they can use (wood, cardboard). Later common materials (steel, concrete) are introduced and at the end of compulsory school modern materials. Materials' properties and use in solving technical problems is studied, and their environmental effects. Preliminary results indicate that some content emerges in all three contexts: material usage, the material's functional properties and origin of the material, production and processing.

Key words: technology education, materials, subject content, classroom, syllabus, text books, experts

Background
Materials, practical purposes, design and construction are key aspects in technology (de Vries 2005). Knowledge of materials is considered as basic in design and product development, as well as in model construction within primary technology education. Within technology education in the compulsory school system in Sweden, the knowledge area of materials is regarded as core content (The Swedish National Agency for Education 2011). In the syllabus it is outlined that pupils should be given the opportunity to work with various materials in their own design work, as well as identifying and analyzing both their own and existing technical solutions with respect to, among other things, materials. However, what kinds of material that are relevant in the school context, and which aspects that should be highlighted, is not explicitly formulated in the syllabus.

A conceptual model regarding technical solutions; *The dual nature of artifacts*, developed by Kroes & Meijers (2000), was introduced into the technology education community by de Vries (2005) According to this model, artifacts can be described on the one hand with the physical properties such as materials, and on the other as objects with functional properties. A previous study (Björkholm 2014) showed that young students, when they referred to the physical properties, primarily focused on the material and its functional properties. Knowledge of materials appears to be relevant to students as they analyze artifacts. Other studies show that young students, when describing different materials, have difficulty distinguishing between the properties of an object

and the properties of the material the object is made of (Cajas 2001). The concept of materials can thus be seen as a relatively abstract phenomenon. Earlier classroom studies have shown that pupils working with own designs develop knowledge in terms of skills regarding, among other things, functional properties of various materials and methods for processing and joining (Björkholm *et al.* 2016). Additionally, conceptual knowledge linked to the materials developed in relation to the objects being produced, such as the name of the material, shape, technical activities and tools (Chatoney 2008), or more general concepts such as malleability (Jones & Moreland 2003). Chatoney (2008), who analyzed the interaction between pupils and teachers in classes where toys were produced, claim that knowledge of materials becomes visible at the beginning of the activities as soon as the objects' functions have been defined, and remain visible throughout the entire process.

Chatoney (2006) also investigated text books and saw how institutional relations to knowledge objects of material at primary school are time fluctuant. However, four knowledge areas seem to persist with stability over time; "naming a few substrates, knowing their origin, knowing a few intrinsic properties, and knowing how to use codes and language" (Chatoney 2006, p.159). These categories are seen as minimal targets for primary technology education. According to Chatoney (ibid.), the concept of materials involves several sciences and technologies in overlapping epistemological fields, and teaching associated to this concept within primary school is a true challenge for the technology teacher.

Even though earlier research indicates different subject content related to materials, there are ambiguities and perhaps also a lack of subject content, among other things, in view of the general educational purpose of the subject of technology in compulsory school. Our starting point is that different aspects of materials are forms of technical knowledge embedded both culturally and historically in technical activities with the aim being produced, consumed and acknowledged as technological solutions (Fleer 2015). Technical knowledge is thus rooted in a specific practice where it fulfills a function. Characteristic of all knowledge is that it develops through both verbal and physical action. Knowledge is, so to speak inherent in the activity itself and is tied to specific situations. Through repeated acts and experiences of the aforementioned, knowledge is developed (Fleer 2015; Schön 1983).

In order to put further light on the field of materials as subject content, and to discuss and specify possible aspects that are relevant for technology education in compulsory school, we want to study how materials as subject content are handled and understood by different actors. Our purpose in this study is therefore to identify and discuss what materials as subject matter may be within the technology subject. This could result in implications for teachers' teaching practice, teacher training, with a new more concrete and broader view on materials.

With our starting point that technical knowledge is rooted in a specific practice, we desire in this project to examine what aspects of materials as subject content in technology education emerge as relevant with the help of different concerned actors in different contexts: the classroom members, the group of experts and the governing documents and text books.

Research question:
What knowledge content in relation to the area of materials within the subject of technology at compulsory school level in Sweden is highlighted among the various actors concerned?

Method
The overall study is based on three sub-studies:

1. An analysis of activities in the technology classroom in primary school

103

2. A study of empirical data based on written statements by materials' experts
3. A review of syllabus and text books

In the first study, two teaching sessions in primary technology education (students 8-9 years old) in two different schools were video recorded. In both classrooms, materials were the subject of focus in the activities but in different ways. One class consisted of a teacher-led classroom discussion focusing on different materials, which was intended as preparation for a student design task. The activities in the second class consisted of student design work where the material was part of the content that was focused upon. The videos were transcribed, and the text was then read iteratively in order to identify categories of aspects of materials that were highlighted in the interaction and activities in the classroom. The data analysis was inspired by the activity theory (Engeström 1987; 1990), focusing on the motives of both teachers and students in relation to the content.

Our theoretical starting point makes us see that any given view of materials science is developed within the practical context where one is situated. In the second study, we have by mail put a question to various experts active in various areas of practice. The question being; what do they consider compulsory school technology teaching should include in terms of materials? They were asked to assume that the teaching would give both general knowledge and a little basic knowledge for further studies. The method chosen for eliciting the expert community's view was inspired by the first round, of a three-stage Delphi study (Murray & Hammons 1995; Osborne *et al.* 2003). Although we only completed the first round, and our method can be regarded as a survey, our starting point shared the Delphi method aims; To improve group decision making by seeking opinions without face-to-face interaction (Delbecq, Van de Ven & Gustafson 1975).The anonymity of participants and the use of questionnaires avoid the problems commonly associated with for example group interviews: reverence to authority, impact of oral facility etc. (Martorella 1991). The Delphi process forces group members to provide written responses and opinions can be received from a group of experts who may be geographically separated (Murray & Hammons 1995).

As technology educators, we (the researchers) have views about the practices of technology education. It was important that these views not impinge on participants' responses. Therefore, very little guidance was given as to the expected content of responses. The procedure seeks to establish the extent of consensus or stability in the community. Brooks (1979) identified consensus as ''a gathering of individual evaluations around a median response, with minimal divergence,'' (p. 378). Commonly, the minimum number for a Delphi panel is considered to be 10 (Cochran, 1983). In this context (*material within education)*, we chose to define experts as those with acknowledged expertise in research or exploring *the materials*. The common element shared by the group was an interest in the materials in their research, producing, or other work. Thus, we sought views from leading scientists (n = 4); producers /managing directors/ (n=4), innovators (n=1) and those engaged in the public understanding of materials (n=1). None of the participants was aware of the identity the other participants. One respondent withdrew and only 9 experts answered our question. Opinions were sought about what ideas about materials should be taught in the school technology through the use of an open-ended questionnaire which asked: What, if anything, do you think should be taught about the materials?

Participants were requested to give a description of each idea to indicate a particular context where they thought a person might find the idea useful and to state why such knowledge would be important for a pupil to know. All the responses were coded reflexively and iteratively. Discussions among three researchers resulted in agreed categorizations of the responses. It resulted in comments from what nine experts think about materials as subject content within the

school technology context. Six themes emerged from this analysis and a summary was composed for each emergent theme, capturing the essence of participants' statements.

In the third study we read the available textbooks in technology for compulsory school. We searched for explicit mentioning of materials or descriptions of technical phenomena and problems where the choice of materials affects the outcome. The purpose of the textbook study and comparison is to find out how materials science and engineering are represented on this intermediate level. There are very few textbooks in technology available in Sweden. The curriculum was revised in 2011, and some publishers have not yet updated their products. The books studied are the following:

Table 1: Books studied

Author(s)	Year	Title [English translation]	Grade (age)
Sjöberg, S.	2013/2003	*Teknik med fysik och kemi* [Technology with physics and chemistry]	1–3 (7–10 yrs)
Sjöberg, S.	2013	*Teknik grundbok* [Technology, fundamental book]	4–6 (10–13 yrs)
Sjöberg, S.	2012	*Teknik* [Technology]	7–9 (13–16 yrs)
Börjesson, G. *et al.*	2008	*Teknik direct* [Technology immediately]	7–9 (13–16 yrs)

The three books by Sjöberg (2012, 2013a, 2013b) all belong to the same series of textbooks, *Puls*, and are intended to be used one after the other.

Findings

The analyses of the teaching sessions show that different aspects of material were highlighted in the different contexts. Naming the materials and giving examples of products made by the material was greatly highlighted in the classroom discussion about materials. The functional properties of different materials and how these properties relate to suitability for use in different products were not brought up specifically by the teacher.

However, the pupils introduced these aspects in the classroom discussion and they contributed e.g. with knowledge of various types of plastic materials and the materials chosen for removal packing boxes from a user perspective, where corrugated cardboard materials were valued as more manageable. In contrast, the issue of the material's functional properties in relation to the object to be manufactured was greatly emphasized in the technology classroom focusing on design and construction work. Pupils were encouraged to try different materials and evaluate their properties and suitability in terms of the design. Naming the materials was not explicitly highlighted in the teaching session. In table 2 (below) different areas of subject content are shown in the two classrooms.

Table 2. The content related to materials highlighted in the two classrooms.

Cat	Technology content materials	Lesson 1		Lesson 2	
		Number of statements	Who initiated the content? Teacher (T) Pupil (P)	Number of statements	Who initiated the content? Teacher (T) Pupil (P)
1	Material related to objects (the material's usage)	66	58 (T) 8 (P)	2	2 (T) 0 (P)
2	Process (shaping, joining etc.) the material in the making of specific objects	5	3 (T) 2 (P)	70	35 (T) 35 (P)
3	Identify and name material groups	45	37 (T) 8 (P)	2	2(T) 0 (P)
4	Evaluating the material in relation to the object's function	21	16 (T) 5 (P)	123	84 (T) 39 (P)
5	Material's constructional properties	12	5 (T) 7 (P)	-	
6	Several different materials in one object	7	1 (T) 6 (P)	-	
7	Material origins	1	0 (T) 1 (P)	-	
8	Name for material = name of object	10	1 (T) 9 (P)	-	
9	Process materials with no connection to the production of items	15	12 (T) 3 (P)	-	
10	Class objects in relation to the material	10	0 (T) 10 (P)	-	
11	Functional properties of materials	15	9 (T) 6 (P)	35	23 (T) 12 (P)
12	Materials from a historical perspective	3	0 (T) 3 (P)	-	
		210	142 (T) 68 (P)	232	146 (T) 86 (P)

In the experts' statements the following themes could be discerned on what the subject matter in relation to knowledge of materials can include.

Table 3. Descriptions of the themes interpreted in the answers from the experts.

Theme for materials knowledge content	Description	Number experts that expressed and developed their ideas on this
Theme 1: the materials' usage	That all products and buildings consist of materials. The material is the prerequisite of technologies and artifacts. The application ("the goals of the problem," the need, purpose, function, context) determines the choice of materials. The material's limitations are significant.	9 of 9
Theme 2: that there are different materials - which kinds?	That there are different material groups and that these groups should be made visible: stone, wood, ceramics, polymers, metals, composites, textile.(Ceramics: clay, brick, glass, concrete)	7 of 9
Theme 3: Material properties	That materials have different properties. The properties depend on how the material is built up. Chemical composition determines the properties: strength, toughness, softness, hard / brittle, temperature resistance, electrical, magnetic, etc. tendencies towards deformations Importance of the 'right' properties. Highlighting the special features. Advantages and disadvantages with different characteristics. The concept of strength. The concept of structures (electrons, atoms, cracks, pores, etc.).	6 of 9
Theme 4: Environmental impact of the material	The material's lifecycle The material's environmental impact. How the material can be recycled. The raw material: how does the raw material affect the world? Human experience of the material, the environments that are created.	6 of 9
Theme 5: How material is formed, refined and changed during use. Also a retrospective view of material production.	The materials have been created by man. How materials are produced, manufactured, processed. Possible methods of production for the material, price, availability. Material is seldom homogeneous, various additives and a structure which has significance (grain size, crystal forms, etc.) The material's historical importance: the Stone Age - Iron Age - Bronze Age etc. How production fits in together with other developments. Development of Swedish material industries (mining, steel, paper, textile, etc.)	5 of 9
Theme 6: New materials	That new materials are developed. Biomimicry - the way we humans mimic nature. That development is rapid thanks to new databases and modeling tools • Nano materials. • Plastic from algae.	4 of 9

The analysis of the syllabus showed, that for the technology subject, the following aspects are mentioned as parts of the subject's core content. (The Swedish National Agency for Education , 2011, pp. 255–258):

Years 1–3   'Materials for their own constructions. Their properties and how they can be combined.

Years 4–6   'Common materials, such as wood, glass and concrete, their properties and use in solid and stable constructions.'

Years 7 – 9   'The importance of properties, such as tensile and compression strength, hardness and elasticity when choosing materials for technical solutions. Properties and applications of a number of new materials.'
'Recycling and reuse of materials in different manufacturing processes. How technological solutions can contribute to sustainable development.'

The syllabus is based on a set of subject abilities and a list of core contents. For the technology subject, the abilities that pupils are to develop are as follows (The Swedish National Agency for Education, 2011, pp. 254–255):
- identify and analyse technological solutions based on their appropriateness and function,
- identify problems and needs that can be solved by means of technology, and work out proposals for solutions,
- use the concepts and expressions of technology,
- assess the consequences of different technological choices for the individual, society and the environment, and
- analyse the driving forces of technological development and how technology has changed over time.

In the four studied books, descriptions about materials appear in the following forms:

Functional characteristics	Copper is a good conductor of electricity.
Actual use	Roof-tiles or sheet metal is used to cover roofs. Bicycle tyres are made of rubber.
Creation or extraction	Glass is made by heating sand (Börjesson)

Discussion
This study aims to examine what subject content in relation to the field of materials in the compulsory school technology subject is highlighted by different actors concerned; classroom teaching, experts, syllabus and text books. Some content emerges in all three contexts: material usage, the material's functional properties and origin of the material, production and processing. Such content is also indicated by Chatoney (2006). Some content appears only among the experts and in the classroom discussion: the material's historical development (by the students), and that there are different material groups (the teachers).

In one of the classrooms, great emphasis is placed to name different materials which is not explicitly highlighted by the experts but is a form of content found in studies by Chatoney (2006). In the technology classroom where students do their own design work, the task comprises a context where knowledge of materials is crucial to the construction being as good as possible, i.e. to realize the desired functions. Naming the material also becomes important and necessary in the interaction between pupils and between teachers and pupils. Experts, however, emphasize themes that do not emerge among the other parties: the material's environmental impact and new materials. In addition, the experts emphasize the importance of explaining the material properties in terms of chemical composition despite the fact that technical features are in focus. In school subjects, chemical and functional properties of chemistry and technology are separated. Consequently, students may not receive explanations of functional properties. If material properties are explained by chemical composition etc. it will be possibly easier to understand the

material's environmental impact and its life cycle. We see the absence of such interdisciplinary aspects in the classroom and in text book.

References

Björkholm, E. (2014). Exploring the capability of evaluating technical solutions: a collaborative study into the primary technology classroom. *International Journal of Technology and Design Education*, *24*(1), 1-18.

Björkholm, E., Andrée, M. & Carlgren, I. (2016) Exploring technical knowledge in the primary technology classroom. *Australasian Journal of Technology Education, 3*(1), 2-16.

Brooks, K.W. (1979). Delphi techniques: Expanding applications. *North Central Association Quarterly*, 53, 377-385.

Cajas, F. (2001). The science/technology interaction: Implications for science literacy. *Journal of Research in Science Teaching, 38*(7), 715-729.

Chatoney, M. (2006). The evolution of knowledge objects in the primary school: A study of the material concept as it is taught in France. *International Journal of Technology and Design Education, 16*(2), 143-161.

Chatoney, M. (2008). Contemplation and use of technical aids in primary school. In J. Ginestié (Ed.). *The Cultural Transmission of Artefacts, Skills and Knowledge: Eleven Studies in Technology Education in France*, 125-147. Rotterdam: Sense Publishers.

Cochran, S.W. (1983). The Delphi method: Formulating and refining group judgements. *Journal of the Human Sciences,* 2, 111-117.

Delbecq, A.L., Van de Ven, A.H., & Gustafson, D.H. (1975). *Group techniques for program planning*. Glenview, IL: Scott Foreman.

De Vries, M. J. (2005). *Teaching about technology. An Introduction to the Philosophy of Technology for Non-philosophers*. Dordrecht: Springer.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research.* Helsinki: Orienta-Konsultit Oy. Retrieved March 28, 2015, http://lchc.ucsd.edu/MCA/Paper/Engestrom/expanding/toc.htm

Engeström, Y. (1990). *Learning, Working and Imaging. Twelve Studies in Activity Theory.* Helsinki: Orienta-Konsultit.

Fleer, M. (2015). Theorising technology education from a Cultural-Historical perspective: foundations and future imaginings. In P.J. Williams *et al.* (eds.), *The Future of Technology* Education, Contemporary Issues in Technology Education, 35-55.

Jones, A. & Moreland, J. (2003). Developing classroom-focused research in technology education, Canadian Journal of Science, Mathematics and Technology Education, 3(1), 51-66.

Kroes, P. A & Meijers, A. W. M.(2000) Introduction: a discipline in search of its identity. In P.

A. Kroes & A. W. M. Meijers (eds), *The Empirical Turn in the Philosophy of Technology*, pp. xvii–xxxv. Oxford: Elsevier Science.

Martorella, P. (1991). Consensus building among social educators: A Delphi study. Theory and Research in Social Education, 19, 83-94.

Murray, J.W. Jr. & Hammons, J.O. (1995). Delphi: A versatile methodology for conducting qualitative research. *Review of Higher Education*, 18, 423-436.

National Curriculum (2011), "Curriculum for the compulsory school, preschool class and the recreation centre", available at: http://www.skolverket.se/publikationer?id=2687 (accessed 15 May 2016).

Osborne, J., Collins, S., Ratcliffe, M., Millar, R., & Duschl, R. (2003). What "Ideas-about-Science" Should Be Taught in School Science? A Delphi Study of the Expert Community. *Journal of Research in Science Teaching, 40*(7), 692-720.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action.* New York: Basic Books.

The Digital Fabrication Laboratories (Fablabs) Platform: A dynamitic Hands-on, Minds-on and Hearts-on Approach to augment STEM Education activities and 21st Century Skills.

Vomaranda Joy Botleng
IMS UMR Université de Bordeaux, France.
vjbotleng@u-bordeaux.fr

Stéphane Brunel
IMS UMR Unversité de Bordeaux, France.
stephane.brunel@u-bordeaux.fr

Philippe Girard
IMS UMR Université de Bordeaux, France.
philippe.girard@u-bordeaux.fr

Abstract

The concept of Digital Fabrication Laboratories (FabLabs), initially targeted at communities as a prototyping platform for local entrepreneurships, is slowly finding its way into educational settings and is used as a platform for learning and innovation. With the current impact of digital technology and when landmark educational reports such as the National Research Council (NRC) are calling for educational reforms, the Fablab platform could be used to augment these efforts to equip individuals with the so-called '21st Century skills'. The Fablab concept also fits in with the pedagogical paradigm shift from a traditional way of learning to a way of learning by doing or constructing. Pappert strongly believed that *'.. knowledge is constructed by using 'manipulative materials' aided by technology'* (Martinez & Stager 2013, p.72) in places like a Fablab. This paper highlights findings from a preliminary observation in a Fablab in France and literature review. The findings indicate three (3) important aspects of Fablabs that qualify it to be used in educational settings to enhance learning, innovation, technological and collaboration skills. These aspects are i) activities in a Fablab constitute a learning approach in line with the pedagogical paradigm shift from 'traditional ways of learning to learning by doing and constructing' aided by technology ii) the Fablab Requirements neatly blend a technological infrastructure and a collaborative learning environment to enhance technological and collaboration skills. Iii) Fab labs adopt an iterative design process that stimulates and sustains learning and move individuals to a higher-order thinking level.

Keywords: Digital Fabrication Laboratories, Iterative design process, cognitive process, collaboration skills

Introduction

Digital Fabrication Laboratories (commonly known as Fablabs), founded by Neil Gershenfeld and his team in the MIT Center for Bits and Atoms (CBA) in Boston in 2003 has a platform that could offer not only industrial and economical benefits, but also educational benefits. According to Gershenfeld (2005), Fablabs are, *'…unlike the web - real and material spaces where people meet face-to-face and produce things together'* (p.ix) using the Fablabs' technological infrastructure for digital fabrication. These include cutting-edge production machinery such as the 3D printers, laser-powered cutters and etchers, table-top milling equipment, high-precision robotic routers

linked to computers running easy-to-run design software. In less than 2 decades, the number of Fablabs has doubled about every 18 months (ibid). This has shown an almost exponential growth (Fig.1). In early 2016, we could identify a total of 638 Fablabs globally spanning from countries in Europe to the nation states of the South Pacific ocean.
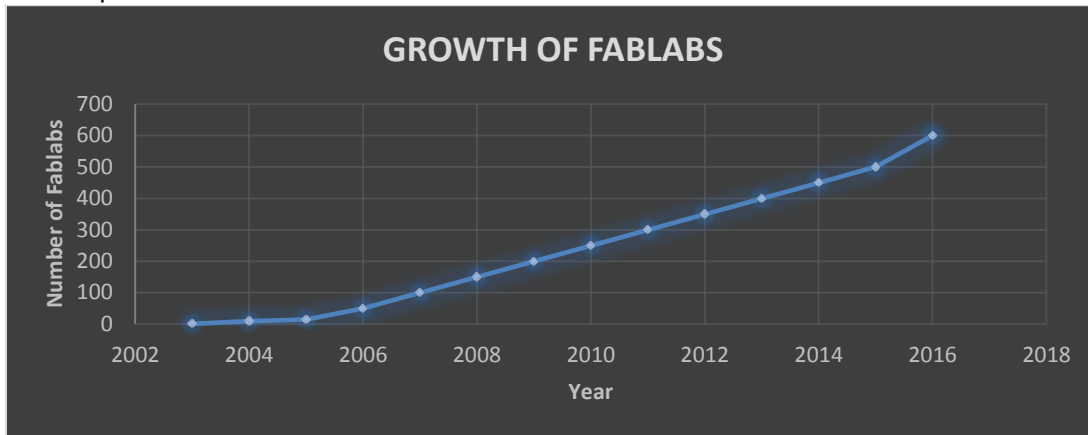
Figure 1: Growth of Fablabs

It is interesting to note that most of these labs are found in Europe (57%) with France alone leading by over 50% of these, followed by the North American region(27%), Latin America and the Caribbean (10%), Asian and Africa (4%), the Middle East (3%) and Oceania, particularly in Australia and New Zealand (1%) (Fig. 2).
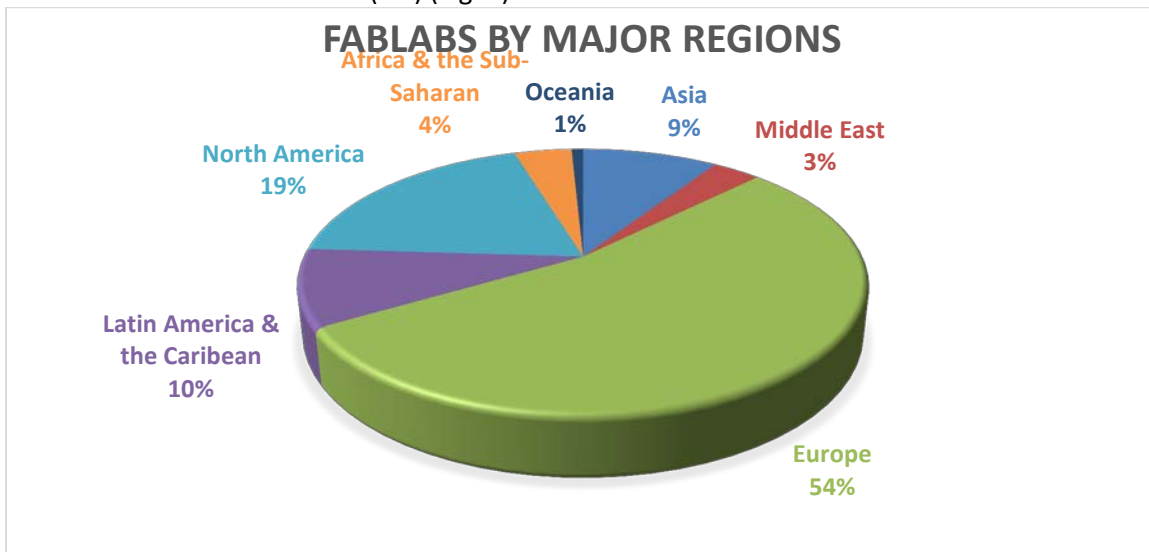
Figure 2 : Distribution of Fabrication Laboratories by major regions.

The emergence of makerspaces such as the Fablabs and the Hackerspace in Europe this century has generated many novel approaches to augment traditional manufacturing processes and encouraged a series of shifts: from 'centralized' mass production towards 'distributed' mass production; from 'dictated' technology towards 'democratized' technology; from 'specialized engineers' towards 'ordinary people'; and from 'uniformed' products towards more customized or personalized products (Gordon 2011).

The concept of Digital Fabrication Laboratories initially targeted for prototyping for Entrepreneurship for local communities is slowly making its way into educational settings and is used as a platform for learning and innovation. In 2008, as part of the Fablab@Schools Project, Paul Blikstein built the first fabrication lab in a School of Education in the U.S where graduate courses were conducted to teach students to design new projects for K-12 education using a fablab (Martinez & Stager 2013). To date, a total of 82 Fablabs have been set up in educational settings of which 57%

are University-based Fablabs, 40% are High School-based and 3% are Elementary school-based Fablabs.

The Literature review and preliminary observations in a Fablab in France outlines 3 aspects of the Fablab platform that qualifies it to be used in educational settings to enhance learning, innovation, technological and collaboration skills.

Aspect 1: Activities in a Fablab constitute a learning approach in line with the pedagogical paradigm shift from 'traditional ways of learning to learning by doing and constructing' aided by technology.

Learning can effectively take place when one **participates** in the **physical and social activities** himself/herself. This theory of learning is not new. It could be traced back to Rouseau's days in the 17th century when he challenged John Loche's famous postulate about the brain being a 'tabula rasa', a concept which Freire later called the 'banking concept'. Other theorists like Jean Piaget, Lev Vygotsky, Maria Montezzori, Froebel, Papert, Pestalozzi and Dewey have echoed this throughout the decades. These **physical activities** range from children playing with toys in a kindergarten to people building houses in a community, or manufacturing a car in a factory.

In makerspaces like the Fablab, these '**activities'** refer specifically to the 'design process' that users iterate through to finally come up with their finished product. According to Eastman (1968), design can be viewed as a type of **problem-solving activity** as it resembles the approach taken by other fields such as the field of chess (de Groot, 1965 ; Newell, Shaw, Simon, 1958) ; for geometry proofs (Gelernter et al, 1960) ; puzzle solving (Newell, 1968) ; and musical composition (Reitman, 1964) where predictions and relocation processes are evident (cited in Eastman 1968, p. 2). These activities alone constitute high-order thinking skills.

One might ask, how then is playing and activities related to design in a Fablab? Do they have some things in common? Edith Ackermann, a colleague of Piaget and Papert who has spent her career investigating the relationship between learning, teaching, design and digital technologies has this to say about play and design:

Both design and play involve breaking loose from habitual ways of thinking, and making dreams come true!' This, in turn, requires 1. an ability to imagine how things could go beyond merely describing or representing how things are (ask what is, do as if, inventing alternative ways) and 2. A desire to give form or expression to things imagined, by projecting them outward (thus making otherwise hidden ideas tangible and shareable). Both are about building and iterating. Messing around with materials, or giving the head a hand often sparks a maker's imagination and sustains her interest and engagement: you get started and the ideas will come. You persevere and the ideas will fly (Ackermann, 2010 in Martinez & Stager 2013, pp 38-39).

Involving oneself in the design process in the Fablabs reinforces Papert's **Constructionist** approach to learning. Papert's Constructionist approach to learning shared Piagert's constructivism's connotation of learning. Papert strongly believes that the knowledge is constructed by using '**manipulative materials'** aided by technology and that '*learning results from experience and that understanding is constructed inside the head of a student, often in a social context*' (Martinez & Stager 2013, p. 72) in places like a Fablab.

Tedious studies and researches over the decades by psychologists, scientists and philosophers like Piaget, Dewey, Montessori, Pappert, Froebel, Pestalozzi and Freire, to name a few (Fig. 3), have strongly emphasised the need for a more robust approach to enhance learning and innovation. The dynamitic approach to constructing in a Fablab aided by technology could therefore lend a strong standing for the Fablab platform to be used to meet that critical need of today's society.

Piaget (1896-1980)

Swiss Psychologist

Froebel (1782-1852). German

Vygotsky(1896-1934). Russian.

Montesorri(1870-1952) Italian

Constructivism – Construction of knowledge happens as one **experiences reality during activities**. Adjustments of mental processes take place to accommodate new experiences. Learning thus takes place.

Kindergarten – Inner reality is presented through play by using **Froebel's 'gifts' (play materials)** that are designed to

Knowledge is constructed through **social** and **cultural context during physical and social activities.** The ZPD and KMO principles form the process of

Scientific pedagogy- children's innate path of psychological development progresses as they **interact** with their environment using **play materials**

FABLAB

Pappert (1928 -) American

Dewey (1859-1952)

Pestalozzi(1746-1827). Swiss

Freire (1921-1997) Brazillian

Constructionism-knowledge is constructed by using **'manipulated materials' aided by** technology.

and significance are established as people test them in **physical**

Self-determined Learning (to be able to do oneself) – **Learning materials** must support learning with the brain, heart and hand, **concept building and**

People are not tabula rasa (Banking concept) to be filled with knowledge. They must **participate and take responsibility** in their own learning. They are beings capable of knowing.

[Photographs: Courtesy of Wikipedia (Biography pages of each Theorist)]

Aspect 2: The Fablab Requirements neatly blend a technological infrastructure and a collaborative learning environment to enhance technological and collaboration skills.

The four (4) Fablab Requirements neatly blends a technological infrastructure and a collaborative learning environment that can enhance technological and collaborative skills.

Requirement 1 : Public access to fablabs – The Open-access status of the Fablab offers an inviting and gender-neutral environment where individuals, including novices, can create or construct. It also allows individuals who just want to experiment with and enhance their practical knowledge of electronics and the high-tech prototyping machines to do so without any external pressures (Martinez & Stager, 2013).

Requirements 2 & 3 : Participate in global Fablab network and collaborate with other Fablabs – This requirement pushes all Fablabs to be connected to the internet to allow access to projects and designs globally. Gershenfeld (2012) used an example to illustrate the wonder of this requirement.

From the Boston lab, a project was started to make antennas, radios and terminals for wireless networks. The design was refined in a fablab in Norway, was tested at one in South Africa, was deployed from one in Afghanistan, and is now running on a self-sustaining commercial basis in Kenya. None of these sites had the critical mass of knowledge to design and produce the networks on its own. But by sharing design files and producing the components locally, they could do so together (p. 11).

The requirement has a built-in meachanism for all users to gain computer skills in order to access the designs and projects. This mechanism is supported by courses run by the MIT Fablab and

supporting organizations like the Fablab Academy and the Fablab Ed. The courses help users acquire these skills to utilise the online designs and projects. In so doing, users enhance their technological and collaborative skills.

Requirement 4 : To share a common set of tools and processes

Machines in the Fablabs are standardised machines proposed by the MIT CBA. The production machines include laser cutters or Computer Numerical Controlled Machines (CNC) and the 3D printers (Fig. 4). Such production machines are able to print, cut or mill objects from from data files.

Fig. 4 : A 3D Printer [Source : Courtesy of Cauderan Fablab, Bordeaux, France]

The standardized computers are the IBM-compatible computers supported by Computer-Aided Engineering (CAE) softwares such as :
  i)   Computer-Aided Design (CAD), the predecessor of the Ivan Sutherland 1963 Sketchpad software (Sutherland 1963)- to draft and draw products (designing).
  ii)   Computer-Aided Manufacturing (CAM) – this software transforms the drawings (designs) done by the CAD into physical models.
The software used in Fablabs are also available under the Open-source (or comparable) licenses therefore are adaptable and developable (Walter-Herrman & Buching, 2013, p.2).

These production machines and software being standardised enhance Fablab collaborations and avoids the problems of compabilitiy of machines between the Fablabs. These production machines and software allow students in educational settings progress from a concept to a prototype that can be tested in the real world.

Aspect 3: Fab labs adopt an iterative design process that stimulates and sustains learning and move individuals to a higher-order thinking level.

The use of computers, CAD and CAM software applications allow iterations between each stage of design thus allows one to enhance cognitive processes at each stage. The Iterative Development Model adopted by the Fablabs (Fig. 5) is believed to be a descendant of Winston Joyce's 'Waterfall Model' of design process. Before the introduction of CAD and CAM programs, Computer Scientists used the Waterfall model to develop computer software, where each stage is planned, build, tested and completed before progressing on to the next stage (Martinez & Stager 2013) without iterating between each stage. The Waterfall Model, however, had some risks. With the introduction of CAD and CAM software, these risks have been reduced and iterations between each stage allows products to become more customized to individual needs as one can '…. *tinker even as you build, spiralling through a series of stages as you make progress* (Martinez & Stager 2013, p.48).
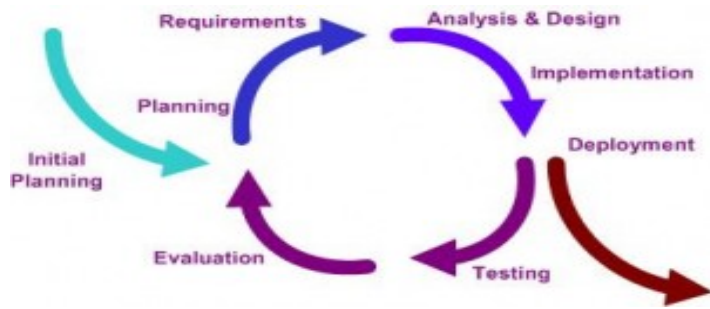
Figure 5: Iterative Development Model
[Source: Martinez & Stager (2013), p. 49]

To align the cognitive processes with the Iterative Development model, the researcher has developed an iterative design process model called the '**Nawita Design Process Model (NDPM)** (Fig. 6). The name 'Nawita' is the Bislama name (bislama is the national language of Vanuatu, an island in the Pacific Ocean) for the sea creature, the 'Octopus'. The name 'Nawita' is specifically chosen for two reasons:

i)   *Resemblance & Cohesion:* The structure of the NDPM closely resembles the physical appearance of a nawita (an octopus). The tentacle-like structures projecting out from each stage of the design holds the stages in the design process together. This signifies cohesion and a robust nature of the model.

ii)   *Camouflage (Adaptive Feature):* A nawita (octopus) can camouflage to adapt to any environment to prevent itself from its predators. In like manner, the NDPM consisting of four simple stages could be easily modified to fit in any type of learning environment.
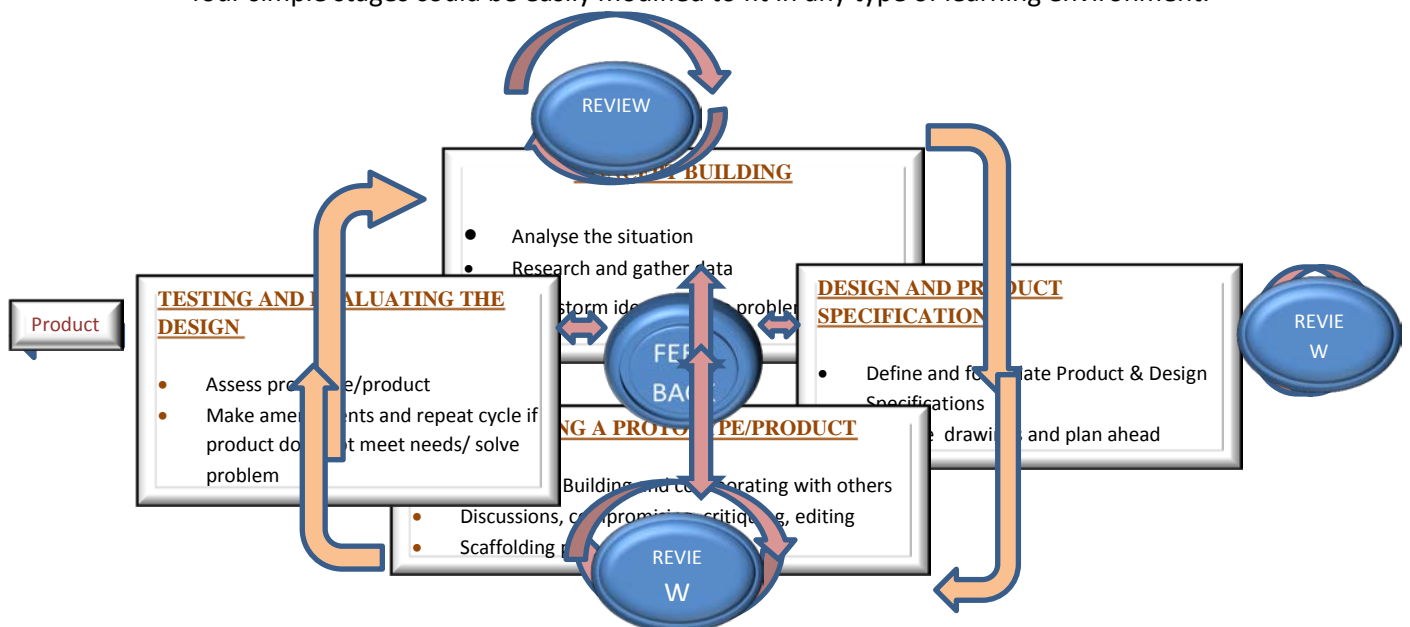
Figure 6 : The Nawita Design Process Model (NDPM).

The NDPM has the *Review and Feedback processes* incorporated for each stage. This allows iterations to take place within the cycle. By constantly reviewing and getting feedbacks from others in the group help correct the mistakes and are more likely to get a more desired result/product at the end. It also helps students to invent different pathways to solving a problem. Martinez and Stager (2013) offers a support by stating that, "… every time the students

take a step forward, backwards or sideways they gain confidence in their own ability to decide what is worth keeping and what is needed to be tweaked ' (p. 76).   According to Rheingold (2011), '*A lot of best experiences come when you are making use of the materials in the world around you, tinkering with the things around you, and coming up with a prototype, getting feedback, and iteratively changing it, and making new ideas, over and over, and adapting to the current situation and the new situations that arise'* (cited in Martinez & Stager 2013, p. 37).

Multiple design cycles like the one presented in NDPM, according to Schunn (2009), "..*enable children to develop children to develop a more complex, more complete understanding of relevant engineering concepts"* (cited in Martinez and Stager , 2013, p. 50). Schunn (2009) further elaborated that at early stages of a design process students *"…tend to focus on superficial aspects of models, often misunderstanding the functional aspects of the design and making poor conceptual connections between models and engineering designs* (ibid), therefore by iterating through the four stages in the NDPM, the students will not only develop a better understanding of technological tools and machines, but it will also help them develop a deeper understanding of engineering concepts. Iteration between each stage of design enhances and sustains learning and moves individuals to a higher-order thinking level.

Conclusion

On a final analysis, the originally targeted community entrepreneurship prototyping platform has, as discussed in this paper, a strong standing for its use as a platform to enhance technological and collaboration skills in educational institutions. Its open-access status and technological infrastructure allows all, irrespective of their gender and abilities to realise their potentials and hence their technological skills and collaboration skills. The utilisation of the constructionist approach to learning in Fablabs offers a robust way to help individuals construct knowledge as they move from concepts to creating their final products. The iterative design process adopted by fablabs help individuals, not only getting more familiar with technology tools and machines but it reinforces the knowledge constructed, sustains learning and moves individuals up to a higher-order thinking level.

References

1. Eastman, C. M. (1968). Explorations of the Cognitive processes in design. *E-journal of Carnegie Mellon University Research Showcase@CMU*. Retrieved July 10, 2015 from http://www.repository.cmu.edu/compsci

2. Gershenfeld, N.A. (2005). *Fab*: *the coming revolution on your desktop—from personal computers to personal fabrication*. New York: Basic Books.

3. Gordon L. (2011). Rapid prototyping for the masses. *Machine Design.com*. Retrieved   April 20, 2016 from http://insidepenton.com/machinedesign/June9RapidPrototypingArticle.pdf

4. Martinez, L.M. & Stager, G. (2013). *Invent to Learn*. Torrance : Constructing Modern Knowledge Press.

5. Papert, S. (1991). Situating Constructionism. In Papert, S. & Harel, I (Eds.), *Contructionism.* Cambridge : MIT Press.

6. Walter-Herrmann, J., & Buching, C. (2013). *Fablab: Of Machines, makers and Inventors.* Hannover : Cultural and Media Studies.

An Investigation into Problem Solving Approaches Adopted During Graphical Reasoning Episodes

Jeffrey Buckley
University of Limerick
jeffrey.buckley@ul.ie

Dr Niall Seery
University of Limerick
niall.seery@ul.ie

Abstract

A core aim of contemporary design and technology education is the development of transferable and robust problem solving skills. Graphical education is a critical component in achieving this aim as it espouses to enhance students' problem solving skills by developing spatial ability through the inclusion of abstract visual problems. In addition to spatial reasoning, modelling is a critical competency associated with problem solving as it can support reasoning by facilitating discourse between a student and their conceptions.

A repeated cross-sectional study design was implemented to gather longitudinal data of student approaches to solving graphical reasoning problems. The study cohort consisted of two consecutive cohorts from Initial Technology Teacher Education (ITTE) programs who were selected based on their engagement in a graphical education module. A battery of psychometric tests of spatial ability was administered to each cohort as well as a selection of graphical tasks within a summative assessment designed to target a selection of cognitive faculties. The results of each measure were analysed through correlational analyses with problem solving strategies for one common graphical problem selected for further analysis.

The findings illustrate higher correlational significance between spatial ability and graphical performance in students with higher levels of spatial ability. A wider adoption of analytical methods and modelling strategies is seen in students with lower levels of spatial ability. Potential rationales are discussed for these findings concerning the adoption of analytical modelling methods and ecological rationality in the selection of problem solving approaches.

Introduction

The development of robust problem solving skills is among one of the most important focusses of contemporary education (Seery & Delahunty, 2015). The need to develop problem solving competencies is predicated by the constantly evolving nature of society in which students need to be equipped to negotiate. As society has advanced into the conceptual age (Pink, 2005) where ubiquitous access to pertinent information has become a reality, education systems need to respond by facilitating the development of cognitive flexibility and supporting fluidity in problem solving. As cultures become more visually orientated (Elkins, 2008), the role of graphical education in espousing visual reasoning capacities becomes increasingly significant, with two of the more prominent capacities meriting development in this domain being internal reasoning and external modelling.

Visual Reasoning

118

Reasoning to solve graphical or visual problems can involve a wide variety of specific reasoning styles. These include among others spatial reasoning, analytical reasoning and geometric reasoning (Linn & Petersen, 1985; Pittalis & Christou, 2010). Graphical education is differentiated within technology education by its unique aim in aspiring to develop visuospatial skills (DES, 2007) and it does this through engaging students in a range of visually orientated problems. These problems implicitly suggest the adoption of a spatial reasoning strategy as they regularly include abstract visual stimuli (Seery, Lynch, & Dunbar, 2011) however there is general consensus that both spatial and analytical reasoning are the two primary types of reasoning involved in spatial tasks (Bodner & Guay, 1997). This would suggest that graphical reasoning predominantly involves either spatial or analytical reasoning or a combination of both. A number of correlational studies have identified a link between spatial ability and performance in graphical education (e.g. Maeda, Yoon, Kim-Kang, & Imbrie, 2013; Sorby, 1999) further suggesting the significance of the role of spatial reasoning during graphical problem solving episodes. However, the associated etiological underpinnings are not well understood. Regarding the adoption of particular styles of reasoning, Linn and Petersen (1985) identified females as preferring analytical approaches with males preferring more holistic spatial approaches to posited spatial tasks. With females regularly cited as having lower levels of spatial ability to males (e.g. Sorby, 2009), the selection of analytical approaches to graphical problems may allude to underdeveloped spatial skills relative to the cognitive load imposed by the problem.

Modelling

Where reasoning capacities are underdeveloped, students can externally model information to provide support when problem solving. Kelly, Kimbell, Patterson, Saxton, and Stables (1987) eloquently describe the interaction between cognitive and external modelling through their dialectic model of the interaction of Mind and Hand. The relationship between modelling and reasoning is interconnected as while modelling can support or alleviate the need to reason, the need can also arise to reason about or while creating the model. Archer (1992a, p.6) defines cognitive modelling as "the basic process by which the human mind construes sense experience to build a coherent conception of external reality and constructs further conceptions of memory and imagination". Archer (1992b, p.7) more generally describes a model as "anything which represents anything else for informational, experimental, evaluative or communicative purposes". Therefore the creation of a model is always intentional but its intent will vary to meet the idiosyncratic needs of its creator. Models do not need to be the "absolute best" (Koen, 1985, p.15) as there role in problem solving is typically to provide a mechanism to support the achievement of a solution. In the context of problem solving, modelling can therefore offer support in multiple forms. For example, the problem solver can create a model to overcome a deficit in cognitive resources at any stage of a given problem or to appraise a solution in whole or in part for confirmation or consolation.

Research Focus

Developing graphical problem solving skills to facilitate flexibility in problem solving is of paramount importance. These skills afford students a wide variety of cognitive tools to support fluidity in the conceptualisation of problem solving approaches. Therefore, this study aimed to explore the potential link between spatial ability and graphical reasoning to examine the utilisation of this capacity. It also sought to investigate student approaches to solving graphical problems with a particular focus on any potential modelling methods adopted by students.

Method

Approach and Participants

A repeated cross-sectional study design was implemented to gather longitudinal data of student approaches to solving graphical reasoning problems. The study was conducted across two cohorts of students in their 3rd year of an Initial Technology Teacher Education (ITTE) program while they

were engaging in a Design and Communication Graphics (DCG) module. The cohorts came from consecutive years, 2014 (N=112) and 2015 (N=103). The students were selected for this study as the graphics module they were engaging with aimed to develop reasoning styles pertinent to solving graphical problems such as spatial and analytical reasoning. The concurrent focus on multiple approaches to problem solving also suggested the appropriateness of these students to participate in this study.

Throughout the module the students completed a variety of psychometric tests designed to measure different spatial factors and as well as a variety of graphical reasoning problems contextualised as an element of a summative examination. Within the library of graphical problems a number of cognitive faculties were targeted, in particular visual processing and domain-specific knowledge (Schneider & McGrew, 2012). Performance in these tasks were subsequently analysed to gain insight into the students' reasoning styles and problem solving approaches.

Design and Implementation

One aim of the study was to examine the potential link between spatial reasoning capacities and problem solving approaches when solving graphical reasoning problems. To facilitate this, psychometric tests of spatial ability were administered to each cohort. For the 2014 cohort, the Purdue Spatial Visualisation Test: Visualisation of Rotations (PSVT:R) (Bodner & Guay, 1997) and the Mental Cutting Test (MCT) (CEEB, 1939) were selected. The PSVT:R is posited to measure the spatial relations factor or the capacity to mentally rotate complex three-dimensional geometries and the MCT is posited to measure the visualisation factor, a general factor of spatial ability describing the universal ability to mentally manipulate visual stimuli. For the 2015 cohort, the PSVT:R was utilised to allow a common measure across cohorts. The MCT was replaced with an adapted Object Perspective Taking Test (OPTT) (Hegarty & Waller, 2004) and the Card Rotations Test (CRT) (Ekstrom, French, Harman, & Derman, 1976). The OPTT measures spatial orientation, a spatial factor describing the capacity to take a different cognitive perspective in space to achieve an additional perspective of a visual stimulus. The CRT measures the speeded rotation factor or the capacity to mentally rotate two-dimensional geometries quickly. The adaption to the OPTT was necessary due to a lack of access to the original test. The adapted test was designed to utilise the exact stimulus and item design as in the original test.

A battery of graphical reasoning problems was also administered to the participants as an element of a summative assessment. Each cohort received a different selection of tasks differentiated only by geometry manipulation while pertinent domain-specific knowledge remained identical. The tasks were designed to encourage a principles based approach to solving the problems to facilitate a degree of flexibility within the solutions. All problems were included in an initial correlational analysis with the students' performance in the spatial ability tests. Following this, one problem which was included for both cohorts with only a minor variation was selected for a more detailed analysis (see Figure 1). This problem was selected as it was a general task where no domain-specific knowledge was required. The task suggested a spatial reasoning approach however it is acknowledged that various modelling strategies and analytical methods could be implemented for support or to audit.
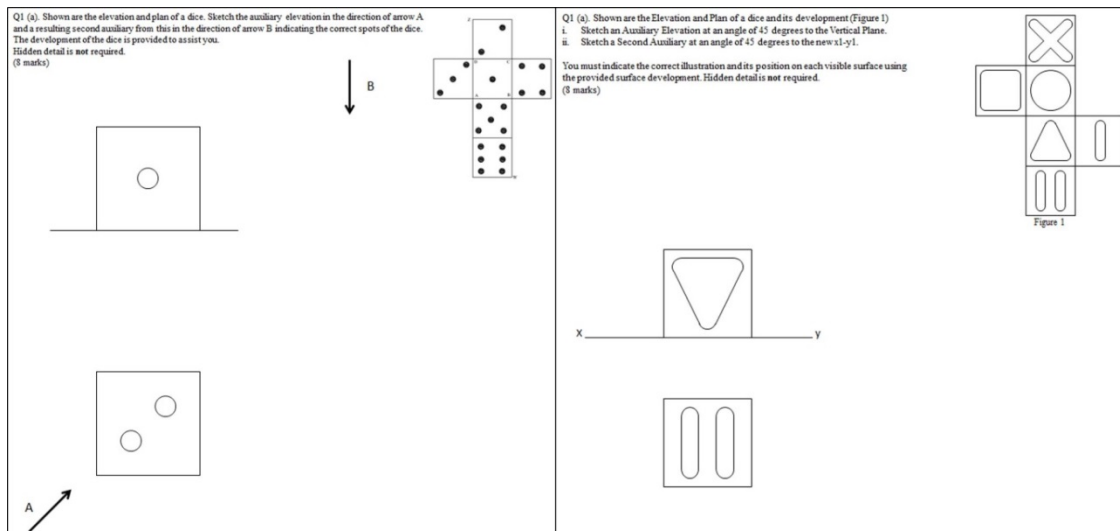
Figure 1: 2014 graphical problem (left) and 2015 graphical problem (right) for case study analysis

The solution to the problem is divided into two parts, the creation of an auxiliary elevation and a subsequent second auxiliary in the directions of the arrows presented in the 2014 problem. Each of these parts was hypothesized to consist of two elements, the identification of the resulting cube and the identification of the correct surface illustrations. The solution for the 2014 problem is illustrated in Figure 2. The only variation in problems between cohorts was that the 2014 problem had surface illustrations modelled after a dice and the 2015 problem replaced these with geometric figures.
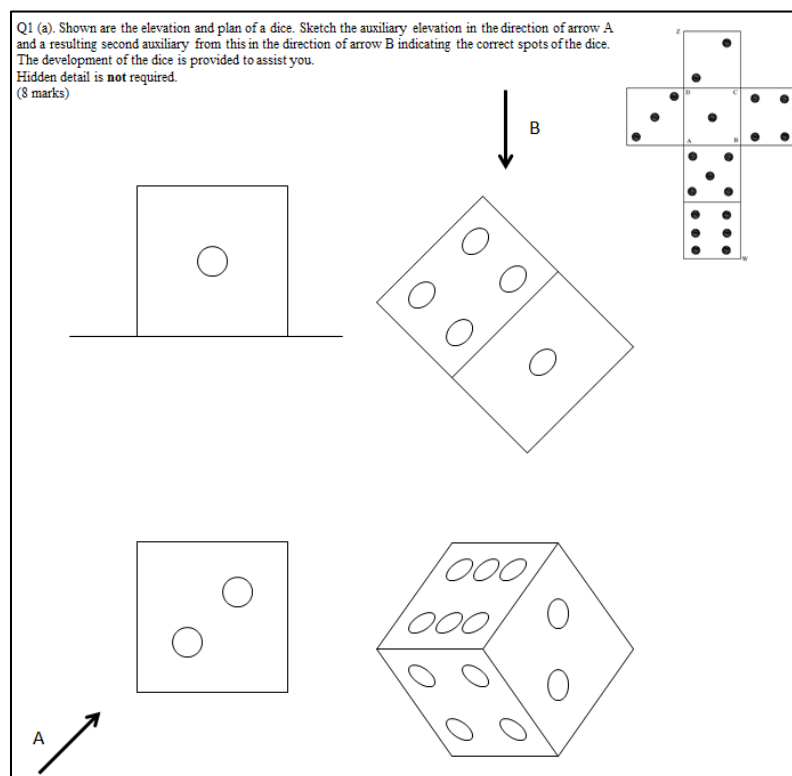
Figure 2: Solution to the 2014 graphical problem

Findings

A correlational analysis was conducted between performance in the psychometric tests and performance in the graphical reasoning problems. The results of this analysis are presented in Table 1. The graphical problems are coded such that problem A1_Cube_Aux_1 refers to problem A part 1 which involves identifying the 1st auxiliary view of a cube.

Table 1: Correlation matrix for scores on psychometric spatial ability tests and performance in graphical reasoning problems

2014 Cohort

		PSVT:R	MCT
PSVT:R	Pearson Correlation	1	.530**
	Sig. (2-tailed)		.000
	N	95	85
MCT	Pearson Correlation	.530**	1
	Sig. (2-tailed)	.000	
	N	85	88
A1_Cube_Aux_1	Pearson Correlation	-.078	-.047
	Sig. (2-tailed)	.450	.667
	N	95	88
A2_Cube_Aux_2	Pearson Correlation	.312**	.413**
	Sig. (2-tailed)	.005	.000
	N	79	74
B1_Plane_Traces	Pearson Correlation	.070	.187
	Sig. (2-tailed)	.620	.188
	N	52	51
C1_Boolean_Modelling	Pearson Correlation	.018	.221
	Sig. (2-tailed)	.878	.062
	N	73	72
C2_Bi_Directional_Associativity	Pearson Correlation	-.050	.102
	Sig. (2-tailed)	.696	.443
	N	63	59
D1_Double_Hyperbola	Pearson Correlation	.139	.072
	Sig. (2-tailed)	.239	.557
	N	74	68
D2_Eccentricity	Pearson Correlation	.115	.201
	Sig. (2-tailed)	.293	.075
	N	85	79
E1_Lamina	Pearson Correlation	.391**	.449**
	Sig. (2-tailed)	.000	.000
	N	85	78
E2_Lamina	Pearson Correlation	.260	.327*
	Sig. (2-tailed)	.065	.025
	N	51	47
F1_Skew_Lines	Pearson Correlation	-.108	.008
	Sig. (2-tailed)	.366	.947
	N	72	67
G1_Tetrahedron	Pearson Correlation	.188	.498**
	Sig. (2-tailed)	.140	.000
	N	63	58
H1_Ellipse	Pearson Correlation	.143	.215
	Sig. (2-tailed)	.184	.053
	N	88	81
H2_Parabola	Pearson Correlation	.274	.087
	Sig. (2-tailed)	.059	.583
	N	48	42
I1_Cube_Tetrahedron	Pearson Correlation	.306*	.491**
	Sig. (2-tailed)	.014	.000
	N	64	57
J1_Pyramid_Intersection	Pearson Correlation	.276*	.311*
	Sig. (2-tailed)	.027	.013
	N	64	63
J2_Prism_Intersection	Pearson Correlation	.225	.362**
	Sig. (2-tailed)	.053	.002
	N	75	71
K1_Development_Envelopment	Pearson Correlation	.305**	.357**
	Sig. (2-tailed)	.007	.002
	N	77	72

2015 Cohort

		PSVT:R	OPTT	CRT
PSVT:R	Pearson Correlation	1	.256*	.369**
	Sig. (2-tailed)		.016	.000
	N	89	88	89
OPTT	Pearson Correlation	.256*	1	.261*
	Sig. (2-tailed)	.016		.014
	N	88	88	88
CRT	Pearson Correlation	.369**	.261*	1
	Sig. (2-tailed)	.000	.014	
	N	89	88	89
A1_Cube_Aux_1	Pearson Correlation	.030	.041	-.081
	Sig. (2-tailed)	.780	.707	.452
	N	89	88	89
A2_Cube_Aux_2	Pearson Correlation	.173	-.036	.046
	Sig. (2-tailed)	.113	.748	.675
	N	85	84	85
B1_Plane_Traces	Pearson Correlation	.004	.163	.028
	Sig. (2-tailed)	.972	.142	.801
	N	84	83	84
C1_CAD_Modelling	Pearson Correlation	.076	.314**	.078
	Sig. (2-tailed)	.519	.006	.504
	N	75	74	75
C2_CAD_Systems	Pearson Correlation	.065	.086	.104
	Sig. (2-tailed)	.623	.515	.428
	N	60	60	60
D1_Parabola	Pearson Correlation	-.038	.048	.112
	Sig. (2-tailed)	.732	.666	.316
	N	83	82	83
D2_Parabola_Tangent	Pearson Correlation	.006	.055	.206
	Sig. (2-tailed)	.960	.615	.055
	N	87	86	87
E1_Plane_Traces	Pearson Correlation	.102	-.053	.005
	Sig. (2-tailed)	.417	.676	.966
	N	66	65	66
F1_Skew_Lines	Pearson Correlation	-.011	.161	.107
	Sig. (2-tailed)	.920	.159	.348
	N	79	78	79
F2_Plane_Traces	Pearson Correlation	.222	.081	.055
	Sig. (2-tailed)	.071	.519	.661
	N	67	66	67
G1_Tetrahedron	Pearson Correlation	.058	.097	.082
	Sig. (2-tailed)	.632	.420	.498
	N	71	71	71
G2_Sphere_Contact	Pearson Correlation	.072	.235	.101
	Sig. (2-tailed)	.646	.133	.519
	N	43	42	43
H1_Hyperbola_Points	Pearson Correlation	.067	.044	-.153
	Sig. (2-tailed)	.615	.748	.251
	N	58	57	58
H2_Hyperbola_Curve	Pearson Correlation	.067	-.075	.009
	Sig. (2-tailed)	.688	.659	.958
	N	38	37	38
H3_Conic_Sections	Pearson Correlation	-.197	.045	.040
	Sig. (2-tailed)	.223	.784	.804
	N	40	39	40
I1_Compound_Pyramid	Pearson Correlation	.056	.153	.107
	Sig. (2-tailed)	.669	.243	.410
	N	61	60	61
I2_True_Shape	Pearson Correlation	-.240	-.076	-.165
	Sig. (2-tailed)	.113	.622	.277
	N	45	45	45
J1_Prism_Intersection	Pearson Correlation	-.209	.145	-.144
	Sig. (2-tailed)	.179	.352	.357
	N	43	43	43
J2_Octahedron_Intersectio	Pearson Correlation	-.124	-.150	.069
	Sig. (2-tailed)	.411	.319	.650
	N	46	46	46
K1_Development	Pearson Correlation	-.056	-.088	-.021
	Sig. (2-tailed)	.618	.437	.849
	N	81	80	81

K2_Envelopment	Pearson Correlation	.137	.024	-.034
	Sig. (2-tailed)	.249	.838	.777
	N	73	73	73
K3_Origami	Pearson Correlation	-.020	-.174	.082
	Sig. (2-tailed)	.894	.253	.594
	N	45	45	45

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

The results indicate very few statistically significant correlations between the spatial tests and performance in the graphical reasoning problems. No significant correlation between a spatial test and graphical problem exceeded an *r* value of .5 with correlations ranging to low (*r* = .276) to moderate (*r* = .498).

To gain additional insight into the problem solving strategies adopted by the participants', further analysis was conducted into the solutions of the one of the graphical reasoning problems as discussed earlier. The approach deemed most appropriate was to separate the participants into quartiles based on their scores in the PSVT:R. An independent-samples t-test was conducted to compare the mean PSVT:R scores between the two cohorts to identify if their results could be combined prior to identifying quartile values. There was not a statistically significant difference in the scores for 2014 cohort (*M* = 76.42, *SD* = 14.90) and 2015 cohort (*M* = 77.86, *SD* = 13.89), *t* (185) = -.684, *p* = .495. A chi-square test of independence was subsequently performed to examine the relationship between participants being in a specific cohort and being in a specific quartile. The relationship between these variables was not significant, χ^2 (3, n = 170) = 1.02, *p* = .797. These results show no evidence of a relationship between cohorts and quartiles and therefore suggest the consideration of all participants as a single cohort was acceptable. Figure 3 illustrates the results of the analysis of all participants PSVT:R results. The boxplot identifies the quartile values (Q1 = 70, Q2 = 76.67, Q3 = 90, Q4 = 100) and the histogram identifies the frequency of the scores achieved by each student.
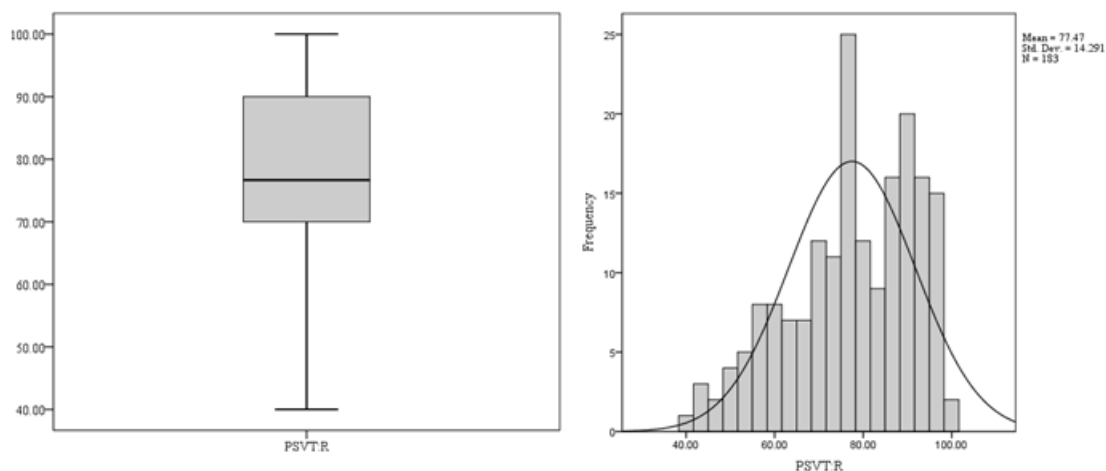
Figure 3: Boxplot (left) to identify quartile values and histogram (right) to identify frequencies of results in the PSVT:R

After identifying the quartiles associated with performance in the PSVT:R, it was determined appropriate to identify if there was any variance in performance in the graphical task across each quartile. The mean performance was calculated for each group and the results are presented in Figure 4. A trend emerged which illustrates that in general, participants with a higher score in the PSVT:R performed better in the graphical task. While there is only a marginal difference between the 2nd and 3rd quartiles, the difference is more prominent between the 1st and 4th. An independent-samples t-test was then conducted to compare the mean performance scores in the graphical problem between the 1st and 4th quartiles as these groups exhibited the highest degree of variance. The results showed no statistically significant difference between the scores for

123

participants in the 1st quartile (*M* = 68.45, *SD* = 22.15) and in the 4th quartile (*M* = 74.79, *SD* = 23.84), *t* (86.858) = -1.299, *p* = .197. Despite the lack of statistical significance, the emergent trend merits further exploration in relation to the strategies utilised within each quartile.
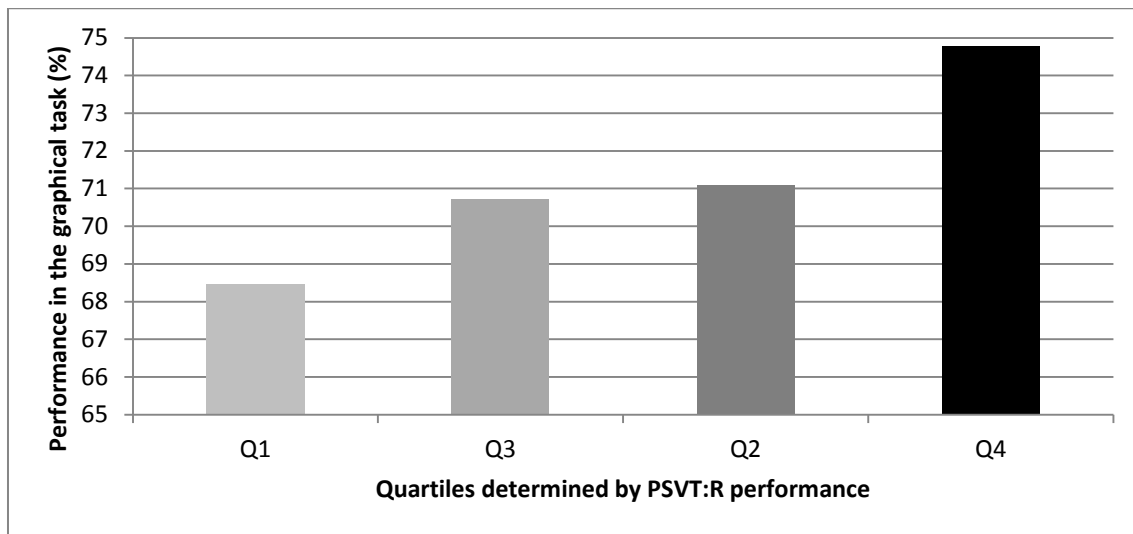
Figure 4: Performance in the graphical task across all quartiles

The next stage of the analysis sought to identify if there was a correlation between the PSVT:R and performance in a specific common graphical problem as previously discussed. The results are shown in Table 2 and indicate that the significance in the correlations increase as the quartiles progress towards the Q1 with the only statistically significant correlations being in the 4th quartile. This would suggest the adoption of a holistic spatial approach as primarily occurring with the participants who had a higher capacity in this reasoning style.

Table 2: Correlations between performance in both parts of the graphical reasoning problem and PSVT:R scores for participants in each quartile

		A1_Cube_Aux_1	A2_Cube_Aux_2
Q1_PSVT:R	Pearson Correlation	-.223	-0.11
	Sig. (2-tailed)	.142	.944
	N	45	45
Q2_PSVT:R	Pearson Correlation	.219	.184
	Sig. (2-tailed)	.316	.401
	N	23	23
Q3_PSVT:R	Pearson Correlation	.179	.186
	Sig. (2-tailed)	.163	.148
	N	62	62
Q4_PSVT:R	Pearson Correlation	.285*	.326*
	Sig. (2-tailed)	.038	.017
	N	53	53

*. Correlation is significant at the 0.05 level (2-tailed).

In order to examine the strategies adopted in solving the graphical problem, the participants' solutions were coded into methods and modelling techniques which were deduced from an observational analysis of their solutions. These methods, depending on their nature, can offer

insight into the efficacy of the cognitive models generated by the students. The solutions illustrated varying strategies to solving the problem both in terms of the nature and quantity of the methods adopted. The resulting methods and descriptions are presented in Table 3.

Table 3: Descriptions of methods and modelling techniques adopted in solving the graphical problems

Method	Description
Adapted Development	Adapting the provided development
Indexing	Indexing the vertices of the cube
Isometric Sketch	Creating an isometric sketch of the cube
Additional Orthographic Information	Illustrating additional surface illustrations in the given orthographic views
Hidden Detail	Adding hidden detail (not required) in their solutions
Illustrations Converted to Numbers	Converting the surface illustrations to numerical figures

To examine the participants' strategies to solving the problems, relationships between each quartile and the problem solving approaches were analysed using a series of Chi-square tests. No test identified any statistical significance between the quartiles and methods however a number of trends were revealed from the analysis.

Figure 5 illustrates the number of methods utilised by participants across quartiles. Of particular interest are the 1st and 4th quartiles. Of all the participants that didn't use any supporting method, 21.1% were in the 1st quartile and 38.6% were in the 4th quartile. Of all the participants that used a combination of 3, 50% were in the 1st quartile and 16.7% were in the 4th quartile. From within these two quartiles, 28.6% of quartile 1 didn't utilise any supporting method while 14.3% utilised a combination of 3 and 46.8% of quartile 4 didn't use any while 4.3% used a combination of 3. This suggests a higher dependency on externalising techniques by the participants in the 1st quartile suggesting either a lower efficacy in their cognitive models or a lower capacity to interact with these models.
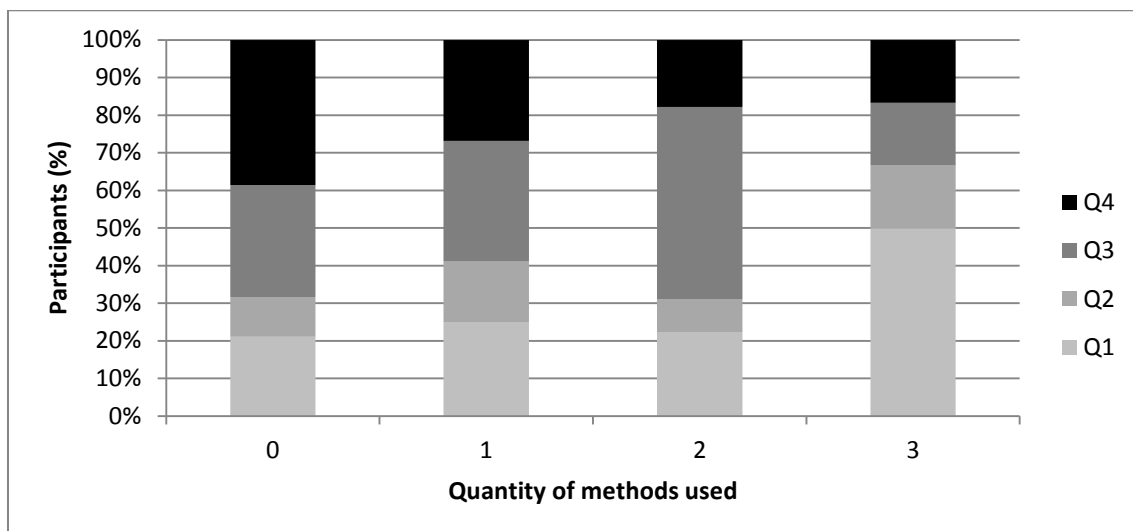
Figure 5: Number of modelling techniques utilised across quartiles

The results of further analysis between the 1st and 4th quartiles in relation to the graphical methods adopted are illustrated in Figure 6. With the exception of adding additional information to the provided orthographic views, each method was used more in the 1st quartile than in the 4th. The largest variances can be seen in the creation of an isometric sketch [23.8%], indexing [11.7%] and

adapting the development [7.6%]. This is of particular interest as it is arguable as these techniques most support the assistance or circumvention of spatial reasoning by alleviating the need to maintain a vivid cognitive model of the geometry.
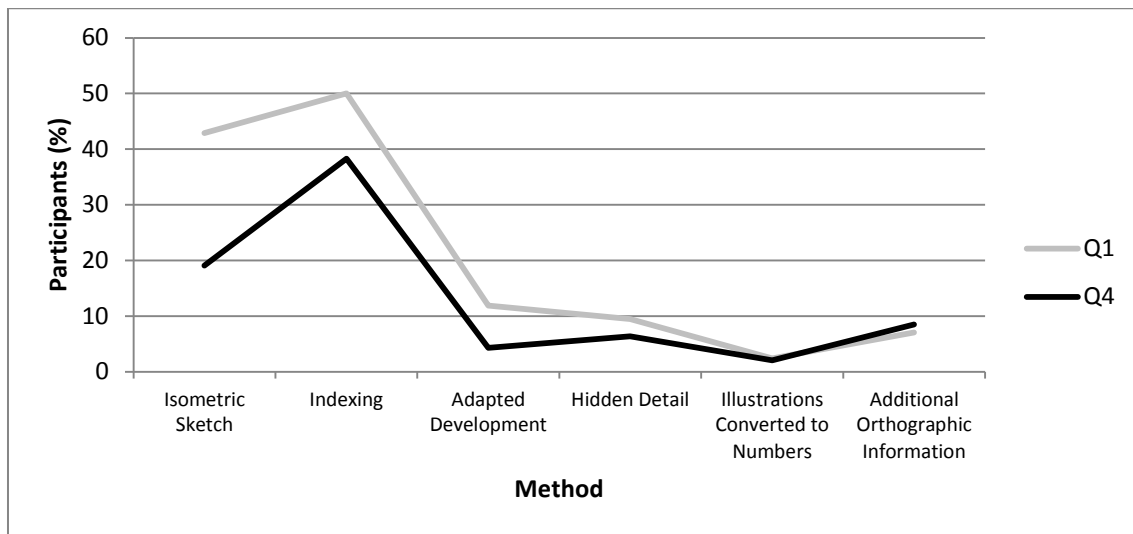
Figure 6: Graphical methods utilised by participants in the 1st and 4th quartiles

Discussion

The findings illustrate that the students who resided in higher quartiles in relation to their level of spatial ability performed better in the graphical tasks and also evidenced a higher dependency of cognitive modelling rather than external or analytical methods. These results align with previous correlational studies which suggests a link between spatial ability and performance in graphical education (Maeda et al., 2013; Sorby, 1999). In the classical theory of problem solving it is theorised that framing a problem involves building a mental representation of its structure known as the *problem space* (Newell & Simon, 1972). Based on the results of this study it is posited that the increased capacity to manipulate a conception within this problem space resulted both in the adoption of more holistic spatial approaches and consequential superior performance in the graphical tasks. The increased efficacy in students' cognitive models for those with higher spatial reasoning capacities resulted in a lower number of instances where an intent to externally model emerged.

With respect to the wider educational agenda of design and technology education where problem-based learning (PBL) is a pedagogical approach characteristic of the discipline, increasing spatial skills has the potential to contribute to the development of cognitive flexibility and an increased fluidity in problem solving approaches. Each student exists within a unique bounded rationality while they engage with a problem in that their decisions are governed by time, information and cognitive computational capacities (Gigerenzer & Goldstein, 1996). Within the problem solving episode the time is task dependant and the information is situated but the cognitive capacities are, in some instances, unbounded. Increasing cognitive capacities within students can offer potentially limitless scope for interactions with thoughts and ideas due to the unbounded realm of the mind which is in direct contrast to limitations which exist in the physical manifestation of a task environment.

However, the human mind is not completely unbounded and cognitive capacities are not entirely limitless. The problem solving space offered within the mind for cognitive modelling is analogous to the dimensionless properties of virtual modelling environments but access to cognitive resources to operate within this space is restricted. Working memory is a particular cognitive competency associated with mental operations and has a restricted capacity (Cowan, 2001;

Miller, 1956). Considering Johnston-Wilder and Mason's (2005) model for effective learning (Figure 7), these cognitive limitations can impede on the manipulation phase. In these circumstances, the creation of physical models can alleviate the cognitive deficits associated with storing the cognitive model. As such, while developing cognitive modelling skills can contribute to problem solving, a critical skill emerges in determining when it is ecologically rational to externalise thoughts and ideas to maintain a fluid discourse for the student with their ideas.
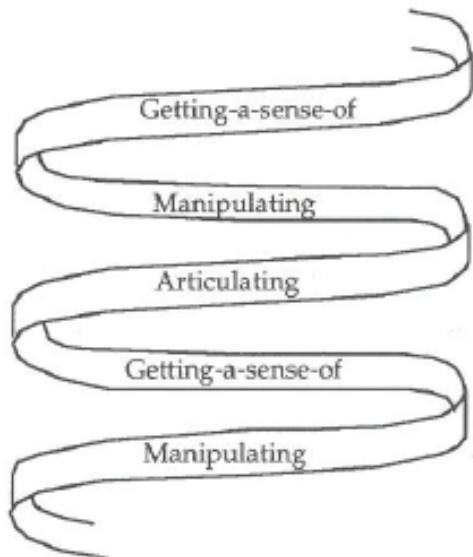
Figure 7: Model for effective learning (Johnston-Wilder & Mason, 2005)

Conclusion

The findings suggest that while engaging with graphical tasks, having an underdeveloped level of spatial ability may stimulate the need to incorporate external modelling techniques into problem solving strategies. It is posited that the creation of the model offers support by removing the need to maintain the cognitive model within the working memory thus allowing more cognitive resources to be allocated to solving the posed problem. Design and technology education is ideally situated to develop both internal and external modelling skills in authentic and meaningful environments. In this study, the findings illustrate that having lower levels of spatial ability resulted in a need to 'think externally' during the problem. For these students, while not implicit within the task, it is likely this was the ecologically optimal solution. As these problems were characteristic of typical graphical problems which are designed to develop or assess spatial reasoning, this raises concerns pertinent to the efficacy of graphical tasks for this purpose. Multiple other cognitive faculties are likely to load on tasks designed to facilitate problem solving development such as processing speed, fluid reasoning and short-term memory (Schneider & McGrew, 2012). Stemming from this study further research is warranted to identify the ecological intent underpinning the use of models relative to the cognitive faculties suggested and employed. An increased understanding into how and why modelling is utilised in association with such faculties would support the development of pedagogical strategies which focus on the development of robust and flexible problem solving skills.

Reference List

Archer, B. (1992a). A Definition of Cognitive Modelling in relation to Design Activity. In P. Roberts, B. Archer, & K. Baynes (Eds.), *Modelling: The Language of Design. Design: Occasional Paper No. 1* (pp. 5–6). Loughborough: Loughborough University.

Archer, B. (1992b). As Complex as ABC. In P. Roberts, B. Archer, & K. Baynes (Eds.), *Modelling: The Language of Design. Design: Occasional Paper No. 1* (pp. 7–11). Loughborough: Loughborough University.

Bodner, G., & Guay, R. (1997). The Purdue Visualization of Rotations Test. *The Chemical Educator*, *2*(4), 1–17.

CEEB. (1939). *Special Aptitude Test in Spatial Relations*. New York: College Entrance Examination Board.

Cowan, N. (2001). The Magical Number 4 in Short-Term Memory: A Reconsideration of Mental Storage Capacity. *Behavioral and Brain Sciences*, *24*(1), 87–114.

DES. (2007). *Leaving Certificate Design and Communication Graphics Syllabus*. Dublin: The Stationery Office.

Ekstrom, R., French, J., Harman, H., & Derman, D. (1976). *Kit of Factor-Referenced Cognitive Tests*. Princeton, New Jersey: Educational Testing Service.

Elkins, J. (2008). *Visual Literacy*. New York: Routledge.

Gigerenzer, G., & Goldstein, D. (1996). Reasoning the Fast and Frugal Way: Models of Bounded Rationality. *Psychological Review*, *103*(4), 650–669.

Hegarty, M., & Waller, D. (2004). A Dissociation Between Mental Rotation and Perspective-Taking Spatial Ability. *Intelligence*, *32*(2), 175–191.

Johnston-Wilder, S., & Mason, J. (2005). *Developing Thinking in Geometry*. London, California and New Delhi: SAGE Publications.

Kelly, A. V., Kimbell, R., Patterson, V. J., Saxton, J., & Stables, K. (1987). *Design and Technology: A Framework for Assessment*. London: HMSO.

Koen, B. V. (1985). *Defintion of The Engineering Method*. Washington, D.C.: American Society for Engineering Education.

Linn, M., & Petersen, A. (1985). Emergence and Characterization of Sex Differences in Spatial Ability: A Meta-Analysis. *Child Development*, *56*(6), 1479–1498.

Maeda, Y., Yoon, S. Y., Kim-Kang, G., & Imbrie, P. K. (2013). Psychometric Properties of the Revised PSVT:R for Measuring First Year Engineering Students' Spatial Ability. *International Journal of Engineering Education*, *29*(3), 763–776.

Miller, G. (1956). The Magical Number Seven, Plus or Minus Two: Some Limits on our Capacity for Processing Information. *Psychological Review*, *63*(2), 81–97.

Newell, A., & Simon, H. (1972). *Human Problem Solving*. New Jersey: Prentice-Hall.

Pink, D. (2005). *A Whole New Mind: Why Right-Brainers Will Rule the Future*. New York: Penguine Group (USA) Inc.

Pittalis, M., & Christou, C. (2010). Types of Reasoning in 3D Geometry Thinking and their Relation with Spatial Ability. *Educational Studies in Mathematics*, *75*(2), 191–212.

Schneider, J., & McGrew, K. (2012). The Cattell-Horn-Carroll Model of Intelligence. In D. Flanagan & P. Harrison (Eds.), *Contemporary Intellectual Assessment: Theories, Tests, and Issues* (3rd ed., pp. 99–144). New York: Guilford Press.

Seery, N., & Delahunty, T. (2015). Cognitive Load as a Key Element of Instructional Design and its Implications for Initial Technology Teacher Education. In M. Chatoney (Ed.), *PATT29*. Palais du Pharo, Marseille, France, 7-10 April: PATT, 364-372.

Seery, N., Lynch, R., & Dunbar, R. (2011). A Review of the Nature, Provision and Progression of Graphical Education in Ireland. In E. Norman & N. Seery (Eds.), *IDATER Online Conference: Graphicacy and Modelling* (pp. 51–68). Loughborough: Design Education Research Group, Loughborough Design School.

Sorby, S. (1999). Developing 3-D Spatial Visualization Skills. *Engineering Design Graphics Journal*, *63*(2), 21–32.

Sorby, S. (2009). Educational Research in Developing 3-D Spatial Skills for Engineering Students. *International Journal of Science Education*, *31*(3), 459–480.

Speculative Multidimensional Time-Line Thinking: a wobbly pedagogy to assist in the process of becoming technologically literate.

John R Dakers
Delft University of Technology
dakers@orange.fr

I have in the past, together with considerable help from others, attempted to "Define Technological Literacy" (Dakers, 2006 - 2014). I have come to realise, however, that the title to this book is somewhat misleading. It does not actually offer a universally accepted definition for the concept of technological literacy. It does offer a variety of important perspectives in that respect, but these perspectives do not, indeed cannot, offer a comprehensive, sustainable and enduring universal definition, one that can be articulated into technology education curricula around the world, delivered and then assessed accordingly, at least, not in current, non-progressive models of educational systems.

This has led me to the understanding that the task that I set myself, the *problem to which I attempted to find a solution*, is essentially impossible. The more I try to seek a universal definition, the more I realise that only partial definitions are possible. Every time I think I have it, something else turns up, something new and unexpected. And what may work for French technology education does not necessarily articulate with the technology curricula of Germany or England or the USA. This is because the concept of technological literacy is both multidimensional and extremely complex. It is neither definable nor fixed. It cannot be determined in advance. It sits, not alone in the essence of technological objects, nor does it occupy exclusively the cultural and social domain: it occupies the liminal spaces between all of these, spaces where transitions between one state and another take place, a space having porous boundaries that are impossible to classify, categorise, situate or define. Technological literacy considered thus, cannot be defined in any other way than that of a metastable construct, an always moving, always changing concept influenced by a continually changing technological and cultural landscape.

In this paper I want to explore the metastable relationship that exists between technology, culture, the natural and the social in terms of technology education. I will argue that this metastable relationship forms an important and crucial part of the concept of becoming technologically literate; something that one never actually becomes, but which one is, rather, always in a process of becoming.

What is technology education in the 21st Century?

This conference is entitled "Technology Education for 21st Century Skills". In its preamble to the conference, the organising committee define technology education as including the following:

"Technology Education is one of the subjects that can be particularly attractive to develop [21st Century] skills. Technology is all about problem solving, creativity, cooperating [and] presenting" (PATT, 2016).

Considering Problem Solving as the Resolving of Problems or as the Generating of New Ideas

On April 13th 1970, Captain James A Lovell, commander of the Apollo 13 mission, contacted mission control in Houston Texas and uttered the now iconic statement: "Houston, we've had a problem"

(often misquoted as we've *got* a problem). Lovell was correct in calling the situation a problem: the oxygen tank in the spacecraft had exploded and this was then followed by other catastrophic events. This was a situation that needed serious attention: it needed to be resolved. Anther problem, admittedly less serious in nature, is that sometimes I experience a breakdown in the signal to my Wifi connection. This is generally resolved by contacting my provider who usually attempts to resolve the problem on my behalf.

The problem that the Apollo 13 mission encountered was, clearly, of a significantly different magnitude to that of my wifi connection. Solutions to the problems occurring in my connection are usually relatively straight forward, and excluding the odd new problem encountered, have, for the most part, been experienced by engineers before. The solutions are, consequently, usually able to be largely determined on site or even in advance and, in my experience, can usually be resolved after one visit by one telecom engineer armed with a van full of readily available technology, technology that is dedicated to resolving most problems associated with wifi systems. Hence, the contents of the vans have been determined, in advance, as being those most likely to be needed to resolve most associated problems. The problem for the spacecraft was markedly different. In order to resolve the problems, engineers had to improvise. There were no available, ready made and dedicated spare parts aboard the spacecraft, nor was there any way to get spare parts delivered to the spacecraft. Engineers had to come up with novel and creative ideas in order to resolve the problem. Experienced and skilled as they were, this problem solving experience took them all well outside their comfort zone. They were dealing with serious risk factors. Yet, strangely what the world remembers is engineers and scientists cooperating in order to come up with novel and creative ideas as to how to get low tech materials, usually stuck together with the equivalent of scotch tape, to resolve incredibly high tech problems. Essentially they focussed on how to gain a surplus, something more than and beyond the already actualised technological assemblage of the spacecraft. It could be argued that this was not rocket science! It did, however, involve all four skills mentioned above, all of which echo what Pye (1968; 20) refers to as the "workmanship of risk". On the other hand, the telecom engineer tends to orientate his skill set around what Pye refers to as "the workmanship of certainty" (*ibid*). The former is not determinable whereas the latter is, or is at least more so. The former is thus, a very much more creative process than the latter. It involves the creation of new ideas, ideas that are much more orientated towards the concept of the invention of something new, something which does not necessarily have to associate with a problem in need of a solution.

Considering the connection between technology, culture, the natural and society and the liminal space they occupy initially.

In conventional thinking, the concept of technological literacy, however it may be conceptualised, is usually linked in some way with society, most commonly in terms of the way technologies impact upon society. Deleuze, Guattari and Simondon, however, dissuade us of this way of thinking. They offer an alternative which, in effect, reverses the conventional. For them, it is society that impacts upon technology.

Mumford (1966) introduces us to the concept of the 'megamachine'. In the construction of the pyramids, for example, Mumford takes us beyond the classical definition of technology considered as a non-human complex artefact. He defines the 'megamachine as a socially constructed machine, that "assembles humans together with materials and other living beings to perform work [all] under human control [hence political]" (Sauvagnargues, 2016: 187). It is in this sense that Deleuze informs us that "machines are social before being technical" (2006: 34). Consequently, any technology, whether in the form of tools or machines, organic or non-organic, has to exist virtually as human thought before becoming actualised in some form. It then must be selected before it is integrated within what Deleuze and Guattari refer to as an assemblage (2004:

442). An assemblage is thus, a consequence of nature, social machines and technological machines interacting within an associated milieu, each influencing one another to the extent that some change in state will possibly eventuate somewhere between a becoming imperceptible or a becoming highly conspicuous. For example, the ongoing erosion that occurs to a mountain over time, due to conditions caused by climate, are imperceptible. Compare this to the highly conspicuous changes occurring in the development of mobile phone technology for example. Each involves some combination of forces, various assemblages, in which a potential for change may occur. In other words, before any change in state can be actualised, whether natural, technological, social, cultural or some aggregation of all, it exists first in a virtual space, a liminal space in which infinite potential actualisations exist only one of which will eventually become actualised. As a result of this process of actualisation, new potentialities are eventuated and further change is made possible. A technology, thus, has its genesis in the virtual, which is social, is made manifest as a technical machine which, in turn, eventuates yet further changes to culture. Deleuze and Guattari offer us the technology of the clock:

"The same machine can be both technical and social, but only when viewed from different perspectives: for example, the clock as a technical machine for measuring uniform time, and as a social machine for reproducing canonical hours and for assuring order in the city" (1985: 141).

Clearly, any analysis of the technology of the clock will be extremely limited if only considered from a technical perspective alone. A more comprehensive understanding requires a technology to be interpreted within the context of its social and cultural milieu. This is a complex process that cannot be pre-determined. It involves, I will argue, a process of speculative thinking.

Speculative multi-dimensional time line thinking

If I were to form a theory or if I were to conjecture about a subject without any firm evidence, I would be speculating. Virtually all formal assessment procedures used in education, tend to frown upon speculation for a number of reasons. One reason for this is that speculative thinking encourages the generation of new ideas, new potentialities that cannot be based upon the creation of pre-determined criterion that has already been established in advance. If so, it would not be speculative. It is in this sense that conventional assessment protocols much prefer knowledge gain that is essentially repetition of *a priori* information or techniques. However, the development of the concept of becoming technologically literate, sits well outside this paradigmatic framework. It is, in contrast, much more in alignment with the concept of formative assessment.

Moreover, and I speculate based upon my own experiences here, evidence confirmed through the medium of measurement made against *a priori* forms of knowledge continues to form the bedrock of technological education assessment protocols. To know the various component parts that go together, as well as the techniques and tools used in the employment of their fabrication, is relatively easy to measure by the formal assessment protocols mentioned above. To know the development of the bicycle since its inception, for example, is also measurable, but only if we accept the time-line of history to be reversible. If not, interpretative creep begins to muddy the waters. To design a bicycle or a cake, as a means to solve a problem, is further able to be measured, provided that the process is clearly defined and adhered to. Usually a portfolio is required which, according to McMillan (2004:235) can be used to "document progress toward the attainment of learning targets or show evidence that a learning target has been achieved". Technology education, governed by evidence based assessment protocols, serves to erode both student and teacher autonomy by insisting upon a regulated conformity of ideas, leading, inexorably, to a loss of identity. Students, teachers and subject matter become specifiable, classifiable and determinable as being students or teachers of *this* or *that* (Deleuze, 2003).

131

Humanity becomes lost in what Fernand Oury referred to as '*encasernée scolaire*' (school as barracks in Cole, 2014: 88). In the preface to their recent book on Deleuze and Guattari, Carlin and Wallin reformulate Deleuze's claim, in educational terms. They say that:

"if life is continually tethered to prior categories of expression, the question of a future not already anticipated by prior habits of thought becomes violently overdetermined. The danger of such overdetermination inheres to the contemporary problems in which much of the Euro-American educational project finds itself today". (2014: xxi)

In order to overcome this, speculative multidimensional time-line thinking has, as its raison d'être, and as expressed in Deleuzian terms, "the fabulating *a* people in the process of becoming, or rather, *a people-yet-to-come*" (Carlin and Wallin, 2014; xxi. emphasis in original). Central to this pedagogy is the necessity to adopt a position of heterodoxy. Heterodoxy, as I define it, supports academic freedom of expression and idea generation where, in a technology education classroom setting, everyone, teachers and students together, are encouraged to discuss concepts relating to the technological past and present. All ideas, past, present or even in terms of the future, are accepted as what Deleuze refers to as "*pas une idée juste, juste une idée'* (not a correct idea, just an idea) The point he makes here, is a follows:

"just [or correct] ideas are always those that conform to accepted meanings or established precepts, they're always ideas that confirm something, even if its something in the future of the revolution. While '[correct] ideas' is a becoming-present, a stammering of ideas [] can only be expressed in the form of questions that tend to confound any answers" (1995: 38-39).

This pedagogy does not lend itself to offering clear, identifiable solutions to what are usually school based problems. Rather, a stammering of ideas interrogates past, present and potential future technological paradigms of expression, in order to then develop and create new and novel forms of technological expression. Problem solving in technology education today, tends to seek what are considered to be correct solutions, solutions that are seen to conform to certain pre-established criterion. A stammering of ideas, however, speculates upon a multitude of potentialities that may, hitherto, have been obscured from perception. Rather than working independently towards designing a problem that seeks a solution, speculative multi-dimensional time-line thinking reorientates the process of thinking about technology. It does this by encouraging new forms of discourse that emphasise cooperative learning. In these scenarios, participants are encouraged to speculate upon what technological problems appear to have been solved by the actualisation of known products and furthermore, to speculate upon how these technological ideas have affected each individual. This immanent perspective serves to personalise the relationship between each participant and the technology in question. The potentialities for discussion are thus infinite and not constrained or restricted by the limited availability of resources.

Considering the bicycle as an example.

What problem did the actualisation of the bicycle solve? Indeed, this leads to the conclusion that it is reasonable to challenge, speculatively, the intentions of the designer/inventor. Was the designer/inventor of the bicycle actually solving a problem or realising an idea? We can only speculate because we can never know the true intentions of a designer, especial one who is no longer living. Ihde calls this the 'designer fallacy' (2014: 119). In the same chapter, Ihde goes on to illustrate that;

 "the design situation is considerably more complex and less transparent than it is usually taken to be. Both the designer-materiality relation, and the artefact-relations are complex and multistable.

While it is clear that a new technology, when put to use, produces changes in practices -[]- these practices are not of any simple 'deterministic' pattern. The results are indeterminate but definite, but also multiple and diverse. Moreover, both intended results and unintended results are unpredictable in any simple way, and yet results are produced" (2014: 128)

It is extremely unlikely that, for example, the designer/inventor of the bicycle foresaw the Tour de France as a potential problem that the bicycle would go on to resolve, if indeed the absence of the Tour de France was problem or was, as Simondon suggests, a superabundant feature. Nor, one can equally speculate, was the bicycle designer likely to have considered how his invention would play a significant role in the women's suffrage movement (Dakers, *in press*). These were only two unintended superabundant features that arose much later as a result of the invention of the bicycle. These superabundant features, problematise the notion of a linear timeline. It is easy to work a timeline in reverse, given that the various events have, to all intents and purposes, already happened, and so be able to claim determinacy. However, it is impossible to determine, in advance, every potential use a new technology will exhibit in the future, as would have been the case for the inventor of the bicycle at that time. One can only speculate historically about intentions. This is why I use the term 'multi-stable time-line'; there are many possible trajectories that a technology might have taken, given the circumstances at the time, or still might take at some other time. As part of the process of becoming technologically literate, learners in technology education settings might wish to speculate on possible alternative trajectories or possible future trajectories. However, they can only do this reasonably by considering any technology alongside its associated milieu at a given time. I shall allow the French Deleuzian and Simondonian philosopher, Anne Sauvagnargues to finish:

No technology she says, "should be studied in isolation without taking into consideration the milieu of individuation that surrounds it and allows it to function. No machine or tool exists by itself, for these artefacts only function in an assembled milieu of individuation, which constitutes its conditions of possibility: there is no hammer without a nail, and thus the interaction between a multitude of technical objects makes the fabrication of nails and hammers possible, whilst also forming the conditions of their utilisation and the practices and habits associated with them" (Sauvagnargues, 2016: 186).

References

Carlin, M., Wallen, J. (2014). Preface. In Carlin, M & Wallen, J (Eds), *Deleuze and Guattari Politics and Education* (pp. xxi-xxvi). New York: Bloomsbury Academic.

Cole, D. R. (2014). Inter-Collapse… Educational Nomadology for a future generation. In Carlin, M & Wallen, J (Eds), *Deleuze and Guattari Politics and Education* (pp. 77-94). New York: Bloomsbury Academic.

Dakers, J. R. (2006). *Defining Technological Literacy: Towards an epistemological framework*. (1st ed.). New York: Palgrave Macmillan.

Dakers, J. R. (2014). *Defining Technological Literacy: Towards an epistemological framework*. (2nd ed.). New York: Palgrave Macmillan.

Dakers, J. R. (*in press*). Taking a Bicycle Ride Into the Virtual with Simondon, Deleuze and Guattari. In (Eds.) Maarten C.A. Van der Sanden and Marc J. de Vries. *Science and Technology Education and Communication.* The Netherlands. Sense Publishers.

Deleuze, G. (1995). *Negotiations, 1972-1990.* (Trans.) M. Joughin. New York. Columbia University Press. [Originally published in 1990 as Pourparles 1972-1990. Paris. Minuit.

Deleuze, G. (2003). *Cinema 2: The Time Image*. Minneapolis. University of Minnesota Press.

Deleuze, G. (2006). *Foucault*. New York. Continuum.

Deleuze, G. Guattari., F. (1985). *Anti-Oedipus, Capitalism and Schizophrenia*. Minneapolis. University of Minnesota Press.

Hadland, T., Lessing, H. E. (2014). *Bicycle Design: An illustrated History*. Massachusetts. The MIT Press.

Ihde, D. (2014). The Designer Fallacy. In Dakers, J. (Ed). *Defining Technological Literacy: Towards an epistemological framework*. (pp 1119-129). New York. Palgrave MacMillan.

McMillan, J. H. (2004), *Classroom assessment: Principles and Practice for Effective Instruction* (3rd ed.), New York. Pearson.

Mumford, L. (1966). The first megamachine. Diogenes, 14. 1-15.

PATT (2016). PATT International Conference website. Available at: http://www.iteaconnect.org/Activities/Calendar/53324.aspx. Accessed 22/April/ 2016.

Pye, D. (1968). *The Nature and Art of Workmanship*. London. The Herbert Press.

Sauvagnargues. A. (2016). *Artmachines: Deleuze, Guattari, Simondon*. (Trans.) Suzanne Verderber. Edinburgh. Edinburgh University Press.

How to teach 'Smart Fashion' within the D&T curriculum: have we got it right?

Sarah Davies
Nottingham Trent University
UK
Sarah.davies@ntu.ac.uk

Alison Hardy
Nottingham Trent University
UK
Alsion.Hardy@ntu.ac.uk

Abstract

The English Design and technology (D&T) curriculum places a greater emphasis on the teaching of electronic systems within a fashion context. E-textiles, are fabrics with embedded electronic circuits that create Smart Fashion products, which interact with the body and environment. Previous research by Davies and Rutland (2014) identified that teachers perceived this kind of curriculum as difficult to design and resource, within the classroom. In this paper we report on some of the initial results from the evaluation of a set of teaching resources, that have been created and tested with teachers, as part of a larger study into how Smart Fashion curriculum can be supported in the classroom. Data collected from the teaching resources and teacher interviews was analysed against current theories of 'best practice'. The findings describe the potential of the resources to support learners in developing an understanding of what e-textiles are and how they can be made. This understanding can then be applied to the designing and making of Smart Fashion products.

Keywords

curriculum reform; e-textiles; teaching resources; tinkering; Smart Fashion

The Introduction

The English National Curriculum (DfE, 2014) and a new D&T examination for 16 year olds (DfE, 2015) places a greater emphasis on knowledge of electronic circuits and programming. This reform, aimed to modernise the curriculum, requires teachers that have traditionally worked within one material area of the D&T curriculum e.g. product design or textile technology, to develop skills across a variety of material areas that integrate electronic systems. One example of this is the inclusion of content that compels teachers to teach pupils about electronic systems within a fashion context.

The integration of electronics within fashion and textiles is an emerging field within interactive design (Seymour, 2008). Flexible circuits that use conductive fabric and small components are termed as soft and allow for ubiquitous computing that can be worn next to the skin and interact with the wearer and their environment (Buechley, 2006). This type of new and emerging technology can be expressed in a variety of ways (see Kettley, 2016 for definitions). For the purpose of this study we will refer to: fashion contexts that draw on interactive technology as (1) Smart Fashion and textiles with embed electronic properties as (2) e-textiles.

Davies and Rutland (2013) conducted small-scale research into previous attempts to modernise curriculum through the integration of electronics and textiles. They found that teachers often

adapted new material and processes to meet existing curriculum aims that didn't match the integrity of the new technology. For example, the use of 'soft' flexible circuits to provide functionality within rigid products that might be more suited to traditional (hard) electronic components. The research also identified a perception amongst the teachers that they lacked the technical knowledge required to design and resource Smart Fashion in the classroom. This establishes the need to develop good quality learning resources to support teachers with the classroom implementation of Smart Fashion education.

In September 2014 the authors secured European Regional Development funding to collaborate with a local small manufacturing enterprise (SME). The aim of the collaborative research project was to investigate how Smart Fashion curriculum can be supported in school. We initially designed teaching resources to support the kind of knowledge learners would need to make e-textiles. It was anticipated that these resources would be the first step in developing technical knowledge that might be later used in Smart Fashion 'design and make' activities (Barlex, 2011). Five teaching resources have been created as part of the project.

In order to be confident that our e-textile teaching resources are of good quality and will support teachers with modernising the curriculum, we needed to evaluate them against current theories of teaching Smart Fashion. In this paper we report on some of the initial results from the first stage, of our on-going project evaluation. Three of the resources will be discussed in this paper, which reports on the first evaluation stage into how the (e-textile) teaching resources meet quality measures. We will explore current thinking on teaching electronic systems through Smart Fashion contexts, to establish a framework for quality.

Literature Review

E-textile teaching resources need to help learners to understand electronic systems and how they might be embedded into flexible textiles. According to Peppler, Gresalfi, Tekinbas and Santo (2013) understanding electronic systems:

involves recognising the elements that structure a system, and, more important, the ways that those elements interconnect to impact each other and the overall function of a system.

(Peppler et al, 2013, p. 21]

This type of knowledge is complex, abstract and perceived by some as difficult (Pulé & McCardle, 2010). With difficult knowledge there is a threat that teachers might rely on transmission models that ask pupils to follow instructions and plan every step, before doing. Resnick & Rosenbaum, (2013, p.164) warn that this kind of pedagogy "saps all spirit from the activity".

So, how do you make difficult knowledge joyful and accessible? Scholars that talk about strategies for dealing with difficult knowledge, share the view that tangible objects can be used to construct understanding, through problem solving activities (Perner-Wilson & Buechley, 2013; Resnick & Rosenbaum, 2013; Wilkinson & Petrich, 2013). Resnick and Rosenbaum (2013) refer to problem solving with objects as 'tinkering' and they go on to argue that these types of activities have the potential to support a wide range of learners.

These scholars draw on the theory of constructionism, which attributes 'objects-to-think-with', as a source of deeper classroom learning (Papert & Harel, 1991). 'Objects-to-think-with' provide a level of transparency that has the potential for pupils to receive instant visual feedback, in relation to the problem they are solving.

Kafai, Fields and Searle (2014) and Ngai, Chan, Cheung and Lau (2010) have conducted research with groups of young people into the way students use physical objects to enhance the learning of electronics and computational concepts. Their work focuses on the aesthetic aspect of making and technological transparency. Ngai et al. (2010) is distinct from that of Kafai et al. (2014) in their

argument that the removal of sewing in the early stage of learning simplifies the process, and, makes learning the concepts less difficult.

Perner-Wilson and Buechley's (2013) research into a 'kit of no parts', exemplifies Papert & Harel's (1991) theory of 'objects-to-think-with' by enabling learners to play with the problem of how to make their own soft electrical component, which expose the inner working of the technology.

Rode et al. (2015) have supplemented the work of Kafai et al. (2014) and Buechley (2006) to develop case study materials that provide an emerging framework for teaching e-textiles. The emerging framework identifies five core skills that contribute to 'best practice' learning in e-textiles. The five skills of: aesthetics, creativity, constructing, visualising multiple representatives and understanding materials form the framework.

Research Design

Having identified current theory about best practice for teaching Smart Fashion we are better able to answer our research question about quality. To do this we used a flexible design (Robson & McCartan, 2016) to collect qualitative data as part of the on-going case study into Smart Fashion education. For this part of the study we are using documentary analysis and teacher interviews (Cohen, Manion & Morrison, 2011). The research adhered to the universities' ethical guidelines and teachers' responses were voluntary and based on informed consent.

The documentary analysis was completed on three of the five resources: (1) Simple Circuit, (2) Make a Soft Switch and (3) Make a soft Battery Holder. Each resource consisted of a tinkering kit and written instructions. The instructions were divided into separate learning steps/stages. Six secondary school teachers tested the resources during a professional development workshop held at the SME HQ. A stimulated recall interview (Schepens, Aelterman, & Van Keer, 2007) was set up to record the teachers' perceptions of how they learnt from the teaching resource activities. The data from the teaching resources and subsequent interviews were analysed using deductive reasoning (Wilson, 2012) against the Rode et al. (2015) framework criteria.

Findings and Analysis:

In this section we will be presenting the findings from the three e-textile teaching resources and teacher interviews.

Opportunities to learn how to construct e-textiles

All three teaching resources contain content designed to support the core skill of constructing. The resources ask learners to physically build simple circuits, using crocodile clips and conductive fabric. They also ask learners to develop traditional textile skills such as: cutting, measuring, hand and machine stitching. The soft component resource requires learners to: (1) join fabric together using hand-stitching with conductive thread and (2) machine stitch pockets and pouches with non-conductive thread. Learners are required to laminate conductive and non-conductive fabric using heat processes.

The teachers that tested the resources, talked about how the instructions for the soft component developed their construction skills through the use of pre-cut fabrics with etched guidelines (to guide the stitching line). Two of the teachers (Teacher A and D), said that these would be very helpful for developing the construction skills required to make Smart Fashion objects with learners, back in the classroom. Teacher D also identified that the conductive thread was "not easy to work with" (Line 231).

From the data we can see that through the range of making skills, including the construction of pockets and encasing conductive fabric within pouches, the resources provide opportunities to

support learners with the skills they need to house electronic circuit within Smart Fashion objects. However, opportunities to practice skills related to using conductive thread on the sewing machine are limited. Teacher D, identifies potential barriers to using the thread which supports the concern Ngai et al. (2010) pinpointed when describing the need to remove sewing from the initial stage of making.

Opportunities to understand Smart Fashion Materials

All three teaching resources contain content that supports the development of material understanding. The two soft component activities challenge learners to apply knowledge of properties when assembling a soft switch and battery holder. The simple circuit resource provided content designed to allow learners to handle and use electronic components and crocodile clips.

When we trialled the resources with the teachers, they mainly talked about the components and their function within the circuit. The teachers talked about how the coin cell positive side "curled around the edge" (Teacher A Line 180) and how this affected the position of conductive elements in the circuit. They talked about how the coin cell differed from their tradition counterpart (pen cell) and one teacher raised the need for health and safety considerations, due to the small size of the components. The teachers also recognised the issue of short circuiting and the need for tight connections to be created with the thread. The teachers talked about current flow and how to break the circuit.

From this data we can see how the activities might provide opportunities for learners to experience and potentially understand Smart Fashion materials and components. This extends the Rode et al (2015) framework to include component understanding alongside materials. The teachers understood how the components interconnected and impacted on the circuit functionality (Peppler et al, 2013) this is essential knowledge for the types of design decisions that are required to design and make flexible Smart Fashion objects that will ultimately be worn next to the body.

Opportunities to creatively problem solve, abstract problems

All three teaching resources contain content that develops learners abstract knowledge. The pedagogical approaches require a level of creative thinking in learners for the active problem to be solved. The switch and battery holder resources allow learners to physically re-engineer existing products or follow step-by-step instructions.

Five of the teachers exchanged thoughts about how the resources helped them to problem solve the circuit design and soft component structure. Teachers D and A talked about how the use of the group activity made the problem solving competitive and Teacher D also acknowledged that working in teams was good for "sharing ideas and working together as a team" (Line 169) to solve abstract problems. Three teachers also identified that the problem solving activities had initially been easy and how this "built my confidence up straight away" (Teacher D, line 161), later the same teacher talks about "flying at first" (line 182) when describing how she solved the problem of making the simple circuit.

From this data we can infer that these teachers gained in confidence through the action of 'tinkering' (Resnick & Rosenbaum, 2013) with tangible objects early on. They later used step-by-step instructions, which may have modified the joy (Resnick & Rosenbaum, 2013). Interestingly the teachers talk about the social nature of the learning provided through the group 'tinkering' activities.

Opportunities to creatively express concrete solutions

The teaching resources are very prescriptive in the main. Only the soft switch resource provided an extension task that gave learners a free reign over decisions, when asked to 'think about other

soft switches that you could make?' This means that opportunities for creative expression are limited across the resources.

Opportunities to visually represent 2D ideas into 3D objects
Three of the four teaching resources include two dimensional (2D) and three dimensional (3D) content. The switch and battery holder resources provide step-by-step instructions that are 2D drawings that need to be interpreted into 3D objects The simple circuit resource requires learners to create a working circuit that lights a light emitting diode (LED), from a bag of separate components and crocodile clips. After completing this the user of the resource is asked to draw a 2D circuit diagram that represents the working circuit they have just created.

Data from the interviews found that the teachers had been "pleased to handle components" (Teacher F, Line 14) and "start fiddling with things" (Teacher A, line 160). The teachers talk about "undoing" (Teacher C, line 69) and re-doing the circuit through the clipping and "quick to unclip" nature of the crocodile clips (Teacher E, line 31). Teacher A discusses how the LED gives her instant feedback when she says that "it is easy to see if you are doing it right or wrong because the end objective, the goal, to get the LED to light up isn't working" (Line 168).

This demonstrates the potential opportunities for learners to work things out in reverse (Resnick & Rosenbaum, 2013). The resources also provide the kind of transparency identified by Parpert and Harel (1991) that provides visual feedback from the LED, to the learner.

Opportunities to make aesthetically pleasing objects
Learners make objects through the two soft component resources. When tested with the teachers, teacher D said "it's always nice, isn't it, to have something physical especially when you have done it yourself" (Line 240). The words aesthetically pleasing never came up and one teacher talked about how the teaching resources had taken "the aesthetics right out of it" because there was no "embellishment" and learning was focussed on "how it was going to work" (Teacher F, Line 84).

From this we can see that the teaching resources don't support opportunities for the making of aesthetically pleasing objects unless the learners see the soft components as 'aesthetically pleasing' because they want (like the teachers) to take the objects home.

Conclusions and next steps
From this study we can start to see that these teaching resources have the potential to support learners in developing an understanding of what e-textiles are and how they can be made. This understanding can then be applied, at a later date, through the designing and making of Smart Fashion products. For these teaching resources to be of quality they need to include opportunities for:
- abstract problem solving,
- the development of material and component understanding,
- experiences in construction techniques required for this kind of hybrid activity (integrated electronics and textiles),
- the visualisation of circuits, simple and advanced and
- group work to support competition and team work.

The next steps in the research project will involve testing the remaining resources with teachers and conducting further enquiry into the social, creative and aesthetic aspects of e-textile learning.

139

References

Barlex, D. (2011). Dear minister, this is why design and technology is a very important subject in the school curriculum. Design and Technology Education: An International Journal, 16(3)

Buechley, L. (2006). A construction kit for electronic textiles. Wearable Computers, 2006 10th IEEE International Symposium on, 83-90.

Cohen, L., Manion, L., & Morrison, K. (2011). Research methods in education (7th ed.). London: Routledge.

Davies, S., & Rutland, M. (2013). Did the UK digital design and technology (DD&T) programme lead to innovative curriculum change within secondary schools? Technology Education for the Future: A Play on Sustainability, Christchurch, New Zealand, 2-6 December. The Technology Environmental Science and Mathematics Education Research Centre, University of Waikato., pp. 115-121.

Department for Education (DfE). (2014). National curriculum. Retrieved from https://www.gov.uk/government/publications/national-curriculum-in-england-design-and-technology-programmes-of-study

Department for Education (DfE). (2015). Guidance GCSE design and technology. Retrieved from https://www.gov.uk/government/publications/gcse-design-and-technology

Kafai, Y. B., Fields, D. A., & Searle, K. A. (2014). Electronic textiles as disruptive designs: Supporting and challenging maker activities in schools. Harvard Educational Review, 84(4), 532-556.

Kettley, S. (2016). Designing with smart textiles. London: Fairchild Books.

Ngai, G., Chan, S. C. F., Cheung, J. C. Y., & Lau, W. W. Y. (2010). Deploying a wearable computing platform for computer education. IEEE Transactions in Learning Technologies, 3(1), 45-55.

Papert, S., & Harel, I. (1991). Situating constructionism. In S. Papert, & I. Harel (Eds.), Constructionism (pp. 1-11) Ablex Publishing Corporation.

Peppler, K., Gresalfi, M., Tekinbas, K. S., & Santo, R. (2014). Soft circuits: Crafting E-fashion with DIY electronics MIT Press.

Perner-Wilson, H., & Buechley, L. (2013). Handcrafting textile sensors. In L. Buechley, K. Peppler, M. Eisenberg & Y. Kafai (Eds.), Textile messages: Dispatches from the world of e-textiles and education (pp. 55-65). Oxford: Peter Lang Publishing Incorporated.

Pulé, S., & McCardle, J. (2010). Developing novel explanatory models for electronics education. Design and Technology Education: An International Journal, 15(2)

Resnick, M., & Rosenbaum, E. (2013). Designing for tinkerability. Design, make, Play: Growing the Next Generation of STEM Innovators, 163-181.

Robson, C., & McCartan, K. (2016). Real world research John Wiley & Sons.

Rode, J. A., Weibert, A., Marshall, A., Aal, K., von Rekowski, T., el Mimoni, H., & Booker, J. (2015). From computational thinking to computational making. Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing, 239-250.

Seymour, S. (2008). Fashionable technology. DE: Springer Verlag.

Schepens, A., Aelterman, A., & Van Keer, H. (2007). Studying learning processes of student teachers with stimulated recall interviews through changes in interactive cognitions. Teaching and Teacher Education, 23(4), 457-472.

Wilkinson, K., & Petrich, M. (2013). The art of tinkering: Meet 150 makers working at the intersection of art, science & technology

Wilson, E. (2012). School-based research: A guide for education students. London: Sage.

Exploring the Relationship between Technology Teachers Orientations towards Teaching and their Associated Professional Life Phases

Andrew Doyle
University of Limerick
andrew.doyle@ul.ie

Dr Niall Seery
University of Limerick
niall.seery@ul.ie

Dr Donal Canty
University of Limerick
donal.canty@ul.ie

Abstract

It is widely agreed that developed pedagogical content knowledge (PCK) is a knowledge base unique to teachers. Therefore, the successful development of a teacher can be evaluated in terms of an evolved PCK. However, research has shown that teachers in later professional life phases (PLP's) are at a greater risk of being less effective (Day & Gu, 2007). Given that the rational and grade point-orientated nature of the Irish education system hinders the development of an integrated pedagogy (Commission on the Points System, 1999; Hennessy, Hinchion, & Mcnamara, 2011), this paper explores the relationship between technology teachers' PLP and their orientations towards teaching as a critical construct of PCK.

The study cohort consisted of practicing technology teachers (n=9) ranging in experience from 4 to 31 years of classroom practice. An interpretive research methodology was employed whereby participants were involved in semi-structured interviews focused on eliciting an understanding of participants' knowledge and beliefs around the purposes and goals of teaching technology. The findings suggest that technology teachers' orientation towards teaching varies as teachers' progress through their teaching career. It emerged that participants in earlier PLP's are more likely to display a pupil-centred orientation towards teaching whereas teachers in later PLP's are inclined to adopt transmission pedagogies suggesting a teacher-centred orientation towards teaching.

Keywords
Technology education, pedagogical content knowledge, professional life phases

Pedagogical Content Knowledge
Pedagogical content knowledge (PCK) is a theoretical construct first introduced by Shulman (1986, p.9) as a way of describing the "particular form of content knowledge that embodies the aspects of content most germane to its teachability". This comprises of ways to represent and formulate a subject to make it comprehensible to others. The academic construct of PCK is recognition that teaching is not simply the transmission of concepts and skills from teacher to students but rather a complex and problematic activity that requires many and varied "on the spot" decisions and responses to students ongoing learning needs (Williams, Eames, Hume, & Lockley, 2012, p.328). Since its inception in the mid-eighties, PCK has garnered much attention, however, as a construct it has proven difficult to define with several hypothesis having been put forward (e.g. Cochran, King, & DeRuiter, 1991; Grossman, 1990; Loughran, Mulhall, & Berry, 2008; Magnusson, Krajcik, &

Borko, 1999). The interconnections that PCK shares with other areas of knowledge such as general pedagogical knowledge or subject-matter knowledge, and the absence of a universally accepted conceptualisation of PCK has led to a debate on the nature of PCK. Some researchers view PCK as an *integrative* knowledge category, void of any unique knowledge form, instead resulting from the amalgamation of other knowledge categories with a particular inner knowledge (Gess-Newsome, 1999). Conversely, PCK is viewed as a separate category of knowledge with its own unique identifiers (Magnusson et al., 1999), and PCK is viewed as a transformation of knowledge from other knowledge categories.

Orientations towards Teaching

Despite the many conceptions of PCK, certain constructs have emerged consistently amongst researchers as being central to PCK (van Driel, Verloop, & de Vos, 1998). Constructs such as knowledge of subject matter (Cochran et al., 1991; Marks, 1990), knowledge of student learning and conceptions (Grossman, 1990; Shulman, 1987), and knowledge of general pedagogy (Grossman, 1990; Marks, 1990) have all emerged as constructs of PCK. However, the consistent emergence of the construct of orientations towards teaching (Anderson & Smith, 1987; Grossman, 1990; Magnusson et al., 1999; Park & Chen, 2012) suggests the importance of this construct in shaping teachers' approach to teaching and learning. Referring to teachers' knowledge and beliefs about the purposes and goals of teaching a subject, the magnitude of this construct is that knowledge and beliefs serve as a *conceptual map* (Magnusson et al., 1999) that guide instructional decisions about issues such as daily objectives, the content of student assignments, the use of textbooks and other curricular materials, and the evaluation of student learning (Borko & Putnam, 1996).

In a recent review of literature investigating science teacher orientations, Friedrichsen, van Driel, and Abell (2011) highlighted concerns with prevailing practices in the research community. Four issues were outlined; (1) the use of the term orientations in different or unclear ways, (2) an unclear or absent relationship between orientations and other model components, (3) assigning teachers to one of the nine orientations outlined by Magnusson et al. (1999), and (4) ignoring the overarching orientations component. A number of precautions were taken in the planning and data analysis stages of this research to ensure that the issues identified by Friedrichsen et al. (2011) were not replicated. Firstly, Friedrichsen et al. (2011) highlighted the inappropriateness of simplistically labelling teachers with one of the nine orientations outlined by Magnusson et al. (1999), citing a lack of empirical grounding to support each orientation. To alleviate this issue, teachers learning activities in this study were not pigeonholed into a set of orientations. An inductive approach to data analysis allowed a more holistic understanding of teachers' orientations to be captured (Issue 3 & 4). The interrelationships between orientations and other model components was not of issue to this research as solely orientations were investigated from the perspective of their influential position within PCK development (Issue 2). Finally, it is important to define exactly what we mean by the term *orientations towards teaching technology* (Issue 1). Although PCK is rather unexplored in technology education, extensive research has been undertaken in science education. As science and technology are strongly interrelated subjects, concepts in both fields are expected to be interchangeable to a large extent (Rohaan, Taconis, & Jochems, 2009). With this view we take inspiration from Friedrichsen et al. (2011) and Magnusson et al. (1999) in describing *orientations towards teaching technology* as; beliefs about the goals or purposes of technology and beliefs about teaching and learning in technology education.

Study Focus

Succeeding Shulman's (1986) introduction to the concept of PCK, many researchers have come to believe that PCK not only exists but contributes to effective teaching, student learning and in turn that high levels of PCK will predict high levels of student achievement (Abell, 2008). This study aimed to investigate teachers' orientations towards teaching from two perspectives.

The first was to investigate teachers' orientations across the spectrum of post-primary education. The second was to typify technology teachers in the context of career progression, aligning teachers from different professional life phases (PLP's, Day & Gu, 2007), working from the assumption that the PCK of teachers in later PLP's should be more evolved. In both contexts, the study focused on identifying common patterns across the knowledge development of different teachers (Borowski et al., 2011; Verloop, van Driel, & Meijer, 2001).

Method

The study cohort consisted of practicing technology teachers (n=9) working at 7 different schools encompassing a wide demographic variation. The inclusion criterion was for all participants to be qualified technology teachers, teaching at both lower and higher level post-primary education at the time the study was conducted. Their teaching experience ranged from 4 to 31 years, their mean experience was 16.3 years with a standard deviation of 9.6. Participants ranged in age from 26 to 53 years, their mean age was 38.6 with a standard deviation of 9.6.

To elicit a holistic understanding of participants' knowledge and beliefs about the purposes and goals of teaching technology, an interpretive research methodology (Cohen, Manion, & Morrison, 2007) was adopted. To prevent capturing highly contextualised data a cross-sectional study spanning the five years of post-primary education was used. A semi-structured interview was used as the sole research tool. The interviews were open ended with the goal of gaining understanding of participants' knowledge and beliefs around the purposes and goals of technology education. Interview questions were designed to encourage participants to lead discussion, enabling reflection on teaching technology. In addition to scripted questions, probing questions (Cohen et al., 2007) were used to further encourage participants to explain the thinking that influenced their pedagogical decision making.

Data analysis was implemented in three phases. The first phase in analysing data involved a discursive analysis of participants' orientations towards teaching technology. Taking cognisance of Friedrichsen et al.'s (2011) statements, an inductive approach to data analysis was adopted for phase one, whereby each participant's orientation towards teaching was categorised into a simple coding system. As advocated by Strauss & Corbin (1998), the coding system was used to identify commonalities and variations in teachers' orientation towards teaching technology. The second phase of analysis involved categorising the results from the discourse analysis into the five years of compulsory schooling. This stage was executed exclusive of participant demographic information, allowing a holistic view of teachers' orientations to be identified as pupil's progress through post-primary technology education. The final phase of data analysis involved realigning the analysed data from phase one with participants' teaching experience to categorise participants into their professional life phases (Day & Gu, 2007).

Findings

The inductive data analysis identified three empirically different orientations towards teaching; teacher-centred orientation, pupil-centred orientation and learning community-centred orientation. A breakdown of participants' orientations as evident from the discourse analysis of their pedagogical approaches is shown in Table 1. It is clear that the majority of pedagogies reflect a teacher-centred orientation towards teaching technology with 60% of all learning activities discussed deemed teacher-centred, irrespective of professional life phase. Qualitative examples from interviews with teachers that reflected a teacher-centred orientation towards teaching include:

We look at the booklets of previous years and we look at the sections that have to be done and we try and go through the design process and the five sections to be completed, starting off at Analysis of Design Brief and they will underline the keywords and discuss it and then they will

move onto Investigation and Research … so then they refine that into a working drawing and the working drawing has to include measurements and details of the joints and so on. The next section is the Manufacture of chosen solution so they take photographs of that as the work progresses and finally then you have the Evaluation. (Participant 7)

I suppose at the start of third year, in September-October, before they even get the brief I would be going through refreshing their minds on the design process, I really go through the design process. For me that would be the main thing, instead of actually students coming up with a sketch and making the project I would actually go through the proper steps … what I feel are the proper steps. (Participant 5)

The above examples reflect the teacher-centred orientation adopted in 60% of the activities discussed. For these activities, participants typically presented structured information about the activity, generally through a presentation or working drawings. The teacher-centred approach was also reflected in the grading criteria with many developing marking schemes, which awarded individual marks for getting specific elements of an activity 'correct', irrespective of a pupils approach or level of cognition. The following examples represent teachers' pedagogies that reflect a pupil-centred orientation towards teaching:

We are going to pick a small wooden object for use in the home, footstool, small stool for sitting on, something for relaxing on, that type of thing. I give them a brief and I will give them an overall measurement, maximum 400 [mm] long and we'll go from there … we take a stool, just an ordinary classroom stool, I get one kid to sit on one and I get him to put his feet up on the other one, and ask him how they feel. They will all complain because their legs are so high, so we get out the measuring tape and we slowly drop the legs down and we get a comfortable height. (Participant 3)

The dimensions they have to figure out at home ... so again we worked out what are the sizes ... what makes it stable, what makes it stand ... they'd go home and measure the sizes of lamps that they were going to use and lampshade because they'd have it with a lampshade. They made it out of cardboard, again that made a model and kind of what made it off of balance. So they figured out the sizes, then we came up with three ranges of the heights here and about three ranges of the base here so they could put them together based on what they wanted themselves. (Participant 9)

The pedagogical approach adopted by participants 3 and 9 allowed a certain level of personal input from pupils, as well as having multiple outcomes. Pedagogies associated with this approach were constructivist in nature, typically consisting of a dialogue between teacher and pupils. This dialectic occurred in a variety of ways, individually, as a group or as a class as a whole. Finally, the following example highlights an excerpt from the data deemed to reflect a learning community-centred orientation towards teaching, exhibited by a single teacher from the participating cohort:

You show them a video of a car that I would have made back in the day, going across a bench and you show how it works. They'll see in the video, how this thing is actually working with the mousetrap and how it powers the car. Similar kind of idea, you get them to work in groups or in pairs … I work with the basic objects, how they could get the car powered, if they were to use pieces of timber or all the apparatus I give to them. Once they come up with a tangible or a solid solution then they'll go ahead into making that. (Participant 1)

Table 4: Teachers' Orientation towards Teaching Technology

Participant	Year Group	Teacher-Centred	Pupil-Centred	Learning Community-Centred
Participant 1	1st		X	
	2nd		X	
	3rd			X
	5th			X
	6th		X	
Participant 2	1st	X		
	2nd		X	
	3rd	X		
	5th	X		
	6th	X		
Participant 3	1st	X		
	2nd		X	
	3rd		X	
	5th	X		
	6th	X		
Participant 4	1st	X		
	2nd		X	
	3rd	X		
	5th		X	
	6th	X		
Participant 5	1st	X		
	2nd		X	
	3rd	X		
	5th	X		
	6th	X		
Participant 6	1st	X		
	2nd		X	
	3rd	X		
	5th		X	
	6th	X		
Participant 7	1st	X		
	2nd		X	
	3rd	X		
	5th	X		
	6th	X		
Participant 8	1st	X		
	2nd		X	
	3rd	X		
	5th		X	
	6th	X		
Participant 9	1st	X		
	2nd		X	
	3rd	X		
	5th		X	
	6th	X		

4th Year is an optional, one year programme offered by 75% of Irish post-primary schools. Due to the lack of a nationally structured curriculum, 4th Year was not included in this study.

The results from the second phase of data analysis are displayed in Figure 1. As previously stated, this analysis was carried out exclusive of participant demographical information, allowing a cross-sectional view of post-primary education. It was found that teacher-centred orientations were most prevalent in the first, third and sixth year of schooling, aligning with the summative assessment at the end of third and sixth years of school. The benefits of fostering a reductionist approach to teaching were outlined by a number of teachers, in particular when discussing learning activities undertaken in examination years.
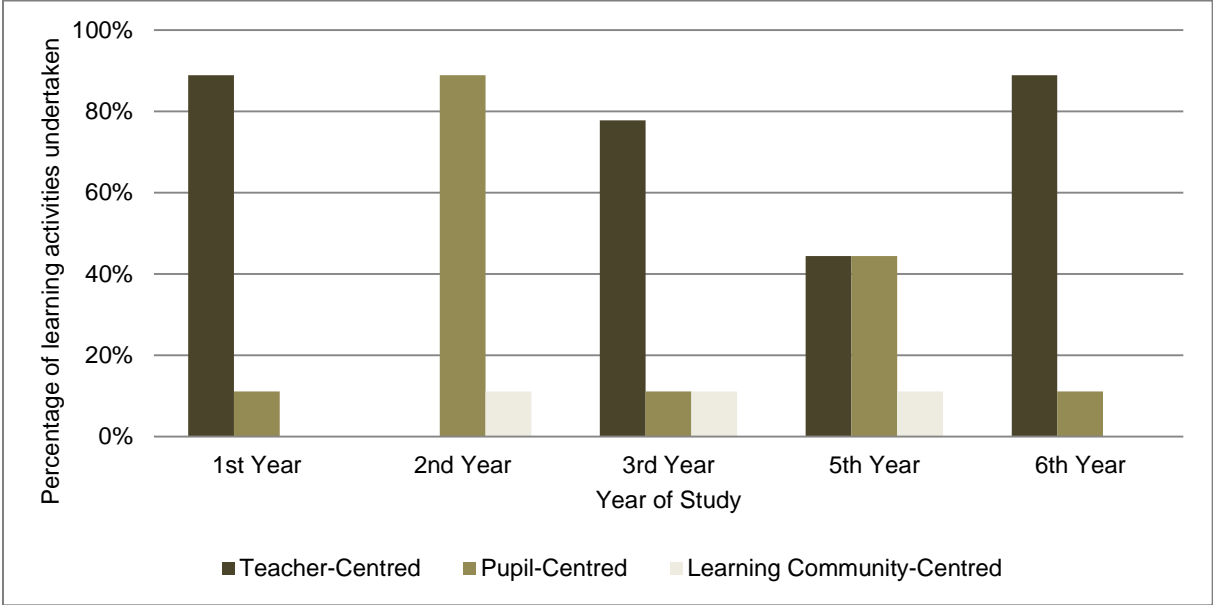
Figure 8: Orientations towards Teaching - Year of Study

The final stage of data analysis involved realigning participants' orientations towards teaching with PLP's. In an effort to identify common patterns across the development of technology teachers, mean scores were calculated for each PLP. Figure 2 shows that only teachers in the second PLP displayed a learning community-centred orientation towards teaching. Participants from the final four PLP's primarily espoused teacher-centred orientations towards teaching, ranging from 60% to 80% of learning activities analysed.
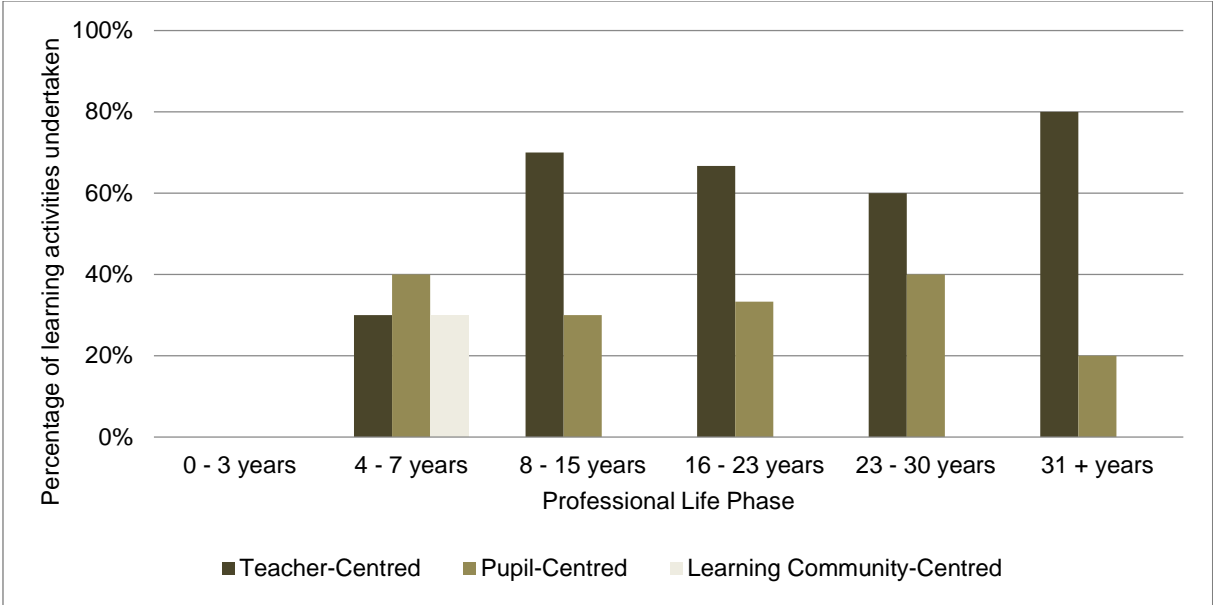
Figure 9: Orientations towards Teaching - Professional Life Phase

146

Discussion

The minority of learning community-centred activities undertaken in examination years in tandem with an over-reliance on didactic teacher-centred activities suggests that the terminal examinations are influencing teachers' orientations towards teaching. Pre-eminent to participants' selection of pedagogies were the influences of terminal assessment as the focus of the third and sixth years of study was the development of technical competencies and leading pupils through the design process as prescribed by the syllabus. The weakness of such models is that they suggest that pupils are not engaged in designing unless they undergo and demonstrate each of the stipulated stages of the process (Atkinson, 1994). Predictability of terminal examination questions offered teachers the convenience of adopting a reductionist approach to teaching the subject. Jones and Moreland (2003) indicate that such an approach is representative of underdeveloped PCK as teachers are reluctant to forge links between the different characteristics of the subject. Superficial compliance in the selective teaching of syllabus content, focusing exclusively on the assessed curriculum, illustrates a lack of constructive alignment (Biggs & Tang, 2011) between the intended learning outcomes and classroom practice. Although participants acknowledge the importance of developing technological capability, the advantages of working solely within the remit of examinable material influences their orientation towards teaching, thus, rendering the development of technological capability a largely utopian aspiration.

Conclusion

It is clear that technology teachers face challenges in terms of pedagogical aspirations and the reality of classroom practice. Within this conceptual tug of war, the prominence of teacher-centred orientations displayed by teachers in latter PLP's illustrates that teachers' orientations towards teaching vary as their career progresses. Porter (2006) states that a knowledge of the assessed curriculum is paramount as pupil achievement is solely measured by the content assessed, accordingly participants in this study are allowing the nature of the assessed curriculum to dictate their orientation towards teaching and in turn, their selection of pedagogies. As evidenced by teachers in this study, a teacher-centred orientation towards teaching technology is the most rewarding in terms of pupil achievement, as pedagogies aligned with such an orientation are effective in preparing pupils for terminal examinations. As long as the assessment system is perceived by teachers to be a means of accountability, teachers will be reluctant to take the risk of abandoning dependable pedagogies.

Limitations & Future Work

Measuring any construct on PCK is a complex process and any teacher evaluation based on a singular data point should be interpreted with caution. When attempting to comprehensively deconstruct, analyse and measure any complex concept in technology education, including PCK, a more robust system must be in place including content assessment, multiple observations and interviews over time. Few studies have addressed the contention that teachers with strong PCK are more likely to increase student achievement (Abell, 2008; Borowski et al., 2011). It is intended that future work will examine teachers at different career stages, inclusive of student achievement results to further unpack the relationship between PCK and PLP's.

References

Abell, S. K. (2008). Twenty Years Later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education*, *30*(10), 1405–1416.

Anderson, C. W., & Smith, E. L. (1987). Teaching Science. In V. Richardson-Koehler (Ed.), *Educators' handbook - a research perspective* (pp. 84–111). New York: Longman.

Atkinson, S. E. (1994). Key factors which affect pupils' performance in technology project work. In J. S. Smith (Ed.), *IDATER 1994* (pp. 30–37). Loughborough, UK: Design and Technology: Loughborough University.

Biggs, J. B., & Tang, C. (2011). *Teaching for quality learning at university: What the student does.* (4th ed.). Berkshire, England: McGraw-Hill Education.

Borko, H., & Putnam, R. T. (1996). Learning to Teach. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of Educational Psychology* (pp. 273–708). New York: MacMillan.

Borowski, A., Carlson, J., Fischer, H. E., Henze, I., Gess-Newsome, J., Kirschner, S., & van Driel, J. (2011). Different Models and Methods To Measure Teachers' Pedagogical Content Knowledge. In *National Association for Research in Science Teaching (NARST)*. Indianapolis.

Cochran, K. F., King, R. A., & DeRuiter, J. A. (1991). Pedagogical Content Knowledge: A Tentative Model for Teacher Preparation. In *American Educational Research Association* (pp. 2–23).

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education.* (6th ed.). London: Routledge.

Commission on the Points System. (1999). *Final Report and Recommendations*. Dublin, Ireland.

Day, C., & Gu, Q. (2007). Variations in the conditions for teachers' professional learning and development: sustaining commitment and effectiveness over a career. *Oxford Review of Education*, *33*(4), 423–443.

Friedrichsen, P., van Driel, J., & Abell, S. K. (2011). Taking a Closer Look at Science Teaching Orientations. *Science Education*, *95*(2), 358–376.

Gess-Newsome, J. (1999). Secondary Teachers' Knowledge and Beliefs about Subject Matter andtheir Impact on Instruction. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining Pedagogical Content Knowledge* (pp. 51–94). Dordrecht: Kluwer Academic Publishers.

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York: Teachers College Press.

Hennessy, J., Hinchion, C., & Mcnamara, P. M. (2011). "The points, the points, the points": Exploring the impact of performance oriented education on the espoused values of Senior Cycle poetry teachers in Ireland. *English Teaching: Practice and Critique*, *10*(1), 181–198.

Jones, A., & Moreland, J. (2003). Considering pedagogical content knowledge in the context of research on teaching: An example from technology. *Waikato Journal of Education*, *9*, 77–89.

Loughran, J., Mulhall, P., & Berry, A. (2008). Exploring Pedagogical Content Knowledge in Science Teacher Education. *International Journal of Science Education*, *30*(10), 1301–1320.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, Sources and Development of Pedaogical Content Knowledge for Science Teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining Pedagogical Content Knowledge* (pp. 96–132). Dordrecht: Kluwer Academic Publishers.

Marks, R. (1990). Pedagogical Content Knowledge: From a Mathematical Case to a Modified Conception. *Journal of Teacher Edcuation*, *41*(3), 3–11.

Park, S., & Chen, Y.-C. (2012). Mapping Out the Integration of the Components of Pedagogical Content Knowledge (PCK): Examples from High School Biology Classrooms. *Journal of Research in Science Teaching*, *49*(7), 922–941.

Porter, A. (2006). Curriculum Assessment. In J. L. Green, G. Camilli, & E. L. Elmore (Eds.), *Handbook of complementary methods in education research* (pp. 141–159). Washington, DC: American Educational Research Association.

Rohaan, E. J., Taconis, R., & Jochems, W. M. G. (2009). Measuring teachers' pedagogical content knowledge in primary technology education. *Research in Science & Technological Education*, *27*(3), 327–338.

Shulman, L. S. (1986). Those who Understand : Knowledge Growth in Teaching. *Educational Researcher*, *15*(2), 4–14.

Shulman, L. S. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review*, *57*(1), 1–23.

Strauss, A. L., & Corbin, J. M. (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*. Sage Publications, Inc.

van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing Science Teachers' Pedagogical Content Knowledge. *Journal of Research in Science Teaching*, *35*(6), 673–695.

Verloop, N., van Driel, J., & Meijer, P. (2001). Teacher knowledge and the knowledge base of teaching. *International Journal of Educational Research*, *35*(5), 441–461.

Williams, J., Eames, C., Hume, A., & Lockley, J. (2012). Promoting pedagogical content knowledge development for early career secondary teachers in science and technology using content representations. *Research in Science & Technological Education*, *30*(3), 327–343.

How Teachers Understand and Implement the Technology Design Process in Quebec High Schools?

Brahim El Fadil, Université de Sherbrooke
Canada
Brahim.elfadil@usherbrooke.ca

Abstract

The introduction of a technology education course in science classes for all Quebec high school students was strongly linked to the recent educational reform. Science and technology teachers were to assume the course load not only of science, but also of the old previous course, Introduction to Technology (Government du Québec, 2004).

Even though most science and technology teachers were not trained in teaching technology education the implementation of the reform occurred (El Fadil, 2015; Hasni, Lenoir, Larose and Squalli, 2012).

This article is the first article in a three-part series presenting the results of this study. The aim of this paper is to present the survey's findings on the implementation of technology design processes (TDP) with the new reform and challenges faced by teachers during the implementation. In a first instance, we shall elaborate on the specific circumstance of technology education in Quebec. Secondly, we will analyze how teachers implement the design process as a basis of technology education. Based on the various results of the survey, we will discuss the impact of teaching the design process on student learning and recommend helpful avenues for technology education teachers.

Keywords: Technology design process, engineering education, technology education, teaching practices, teaching challenges

1. TECHNOLOGY EDUCATION IN QUEBEC

1.1 Technology Education in Quebec Program

In the province of Quebec, Canada, the latest curriculum reform for secondary school creates a single discipline, called Science and Technology (ST), by integrating five scientific fields (astronomy, biology, chemistry, geology and physics) and technology.

The new program views ST as integral parts of societies because they represent both an important aspect of our cultural heritage and are key factors in our development. Consequently, it is important to help students gradually develop their technological literacy and to understand the role that such a literacy plays in their ability to make informed decisions and their discovery of the pleasures of technology. In order to solve problems or form opinions about major scientific and technological issues it is often necessary that the student be able to refer to subject matter and methods from several fields at once.

To deliver the technological literacy, the Quebec Education Program aims at the development of the three following competencies:

– *Seeks answers or solutions to scientific or technological problems;*
– *Makes the most of his/her knowledge of ST;*
– *Communicates in the languages used in ST.* (p. 2)

The first competency focuses on the methodology used to solve technological problems.

The second competency focuses on students' ability to apply what they have learned in ST, especially when dealing with real-life issues.

The third competency encompasses the different types of language used in technology essential for sharing information as well as for interpreting and producing technological messages.

1.2 Cross-curricular competencies

In order to build strong technological literacy, the Quebec Program puts forward the development of cross-curricular competencies. These general competencies are not developed at a theoretical level; they are rooted in specific learning contexts, usually subject-related. These cross-curricular competencies are organized into the following four categories: (1) Intellectual Competencies; (2) Methodological Competencies; (3) Personal and Social Competencies; and (4) Communication-Related Competencies.

1.3 TDP in Quebec Education Program

The Quebec Program emphasizes that every learning and evaluation situation should enable students to develop every aspect of the targeted competency. Therefore, students must be encouraged to make decisions, or use a more hands-on approach, such as the TDP. In developing these situations, teachers should highlight a hands-on approach. This puts ST teachers in a confusing state. Indeed, many studies, conducted in the Quebec context, show that most in service ST teachers have pointed out a lack of training in their own discipline, especially in TDP (El Fadil, 2015; Hasni, Lenoir and Froelich, 2015).

In this new shift, it is important to verify how teachers deal with the TDP in their practices. This paper reports on findings from an inquiry, by interview, into the implementing of the TDP across the secondary level in the province.

The research questions that guided this study are:

• How do teachers implement the TDP in their classroom?

• What challenges and barriers are faced by technology teachers when seeking to implement TDP?

2. LITERATURE REVIEW

2.1 TDP in the literature

Technology education is an emerging school discipline aimed at preparing students for the world of tomorrow (English, Hudson, and Dawes 2012). It allows schools to foster not only an understanding of technology in society, but also to contextualize science and mathematic principles and promote the design process. Furthermore, Boregford-Parnell, Deibel and Atman (2010) support that addressing the TDP as part of the middle school curriculum can significantly enhance students' problem-solving abilities. Many others note that the TDP can be a challenging subject to teach because "design thinking" is characterized by a set of skills that include tolerating ambiguity, dealing with uncertainty, using estimates and simulations, and experiments to make effective decisions (Dym, Agogino, Eris, Frey and Leifer, 2005). It involves working on *ill-structured* problems, which often have multiple solutions (Tate, Chandler, Fontenot and Talkmitt, 2010).

Daugherty (2009) argues that this new discipline has enough curricular flexibility to encompass a considerable variety of approaches to the infusion of design and engineering. According to Daugherty (2012), there are two distinct philosophies of teaching technology education: (1) a pre-engineering perspective that focuses on developing an engineering pathway for capable students; and (2) an engineering literacy perspective that views engineering knowledge as important for all students.

In the same optic, many other technology educators suggest TDP as a curricular focus for technology education to achieve technological literacy (Wicklein, 2006).

Consistent with ITEA (2007), technological literacy means the act of making or crafting, but more generally it refers to the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants. Generally speaking, developing a technological literacy means to understand the basic elements that go into any technology, such as the TDP. This process is the main approach that designers use to create solutions to technological problems. Another element is development and production whereby the design is transformed into a finished product.

To make it clear, de Vries (2005) argues that it is important to identify the essential knowledge and concepts that children need in order to develop their understanding. Consistent with Barlex (2011), the key concepts for design and technology are *designing*, *making*, *resources* and their characteristics, *control*, *structures*, *systems*, and *the made world*.

2.2   Teaching practices: how teachers deal with TDP in their classroom

Regarding the teaching approaches, Hmelo, Holton, and Kolodner (2000) argue that design activities are "well-suited for helping learners understand systems because of their emphasis on functional specification and their requirement that behavior be implemented" (p 251). Given a set of constraints and specifications, designers must create an artefact in order to accomplish the desired functions. The functional requirements and iterations that occur in design afford opportunities for students to understand ST concepts and apply those understandings to the design (Daugherty, 2012). This knowledge is often created through the actions such as design process.

As to the classroom-learning situation, the results of the Lee and Cho (2007) study indicate that students were more likely to find appropriate and elaborate problems in the *ill-structured* scenario than in the *well-structured* scenario. Undeniably, Franske (2009) shows that in the *ill-structured* situation, scientific knowledge was a predictor of problem finding performance, and conversely, *ill-structured* problem finding performance may be indicative of knowledge acquisition and useful for knowledge assessment.

According to English et al. (2012), the TDP can enrich the broader school curriculum in that it: is highly iterative; may have more than one possible solution; provides meaningful contexts for learning mathematical, scientific and technological concepts; provides a stimulus for dealing with complex systems. Regarding strategies, Barlex (2011) identifies four following broad approaches for teaching design and technology education: (1) *Making without designing*; (2) *Designing without making*; (3) *Designing and making*; and, (4) *Exploring the technology and society relationship*.

In *making without designing*, students work collaboratively, use plans provided by the teacher and a set of part prepared materials to produce a finished artefact. Students have the opportunity to develop technical skills within their group. However, if all the design situations were of that type, sure, they will be attractive, but there would be significant omissions with respect to a balanced design and technology education.

In *designing without making*, students work collaboratively in designing but not making artefacts. Many studies show that strategy leads students to the use of computers and new technology. However a design activity that consisted simply of such exercises would not provide a balanced approach to design and technology.

Concerning the *designing and making*, it is often seen as the heartland of technology education even though it does not reflect the reality of technological activity in the world outside school where those who design artefacts are usually not those who manufacture them. The significance of this perspective consists on the student's decision making. Barlex summarizes that the decision making that students have to undertake when they are designing and making has been described as involving five key areas of interdependent design decision: conceptual, technical, aesthetic, constructional and marketing.

Respecting *exploring the technology* and society relationship, Layton (1995) argues that developing critique competence in young students with regard to technology is a very important facet of technology education. Therefore, Barlex (2011) advocates that a school design and technology program that did not engage students with exploring our ambivalent relationship with technology would seem to be missing an essential ingredient.

While recent school technology programs have focused on technology and design process, there has been limited research about how teachers implement that process in their classrooms (Potter, 2011).

3. METHOD

This descriptive study examined the degree to which technology teachers were implementing elements of TDP in their classrooms. Nineteen participants were selected, using convenience sampling. The criteria applied to the selection of our sample were that the participants teach technology education in the current year and their acknowledgement that they are using the TDP in their practices. Despite the fact that all participants taught technology education and design process, the majority (n=11) of them have not been trained in technology education. Only six teachers said that they have been trained in technology; while two others said that they were trained in engineering fields. All participants said that they have taught the TDP in high school for many years.

There were two dependent variables for this study. The first was the implementation of the TDP in classroom practices. To measure the implementation of the TDP, we asked teachers to describe to us one or two of the latest design activities implemented in their classes. Eight participants described two teaching situations and eleven described one situation each. A total of 27 situations were on the discussion menu. To analyze the collected data, categories were generated not only from our conceptual framework, but also from The Quebec Education Program's elements. The second dependent variable is related to challenges. We asked teachers to describe to us what challenges or barriers they faced when seeking to implement the TDP.

All teacher interviews were recorded, transcribed verbatim, coded and analyzed based on the techniques of thematic categorization (Bardin, 2007).

4. RESULTS AND DISCUSSION

The results of the interviews are grouped according to the research questions that guided the study.

TDP implementation

The first research question asked teachers to describe how they implement one or two teaching and learning situations in the context of TDP. The intention was to investigate the approaches taken by teacher participants in implementing the TDP at the high school level. These issues were grouped into two primary themes concerning the modalities of implementing the TDP: (*a*) Mode including a *well-structured* problem; (*b*) Mode without a problem. The second level of analysis shows that the first mode can be divided into two distinguished modalities: (*a1*) modality aligned with the inquiry method; and (*a2*) modality based on trial and error. These modalities are represented visually as shown in Figure 1 below.

153
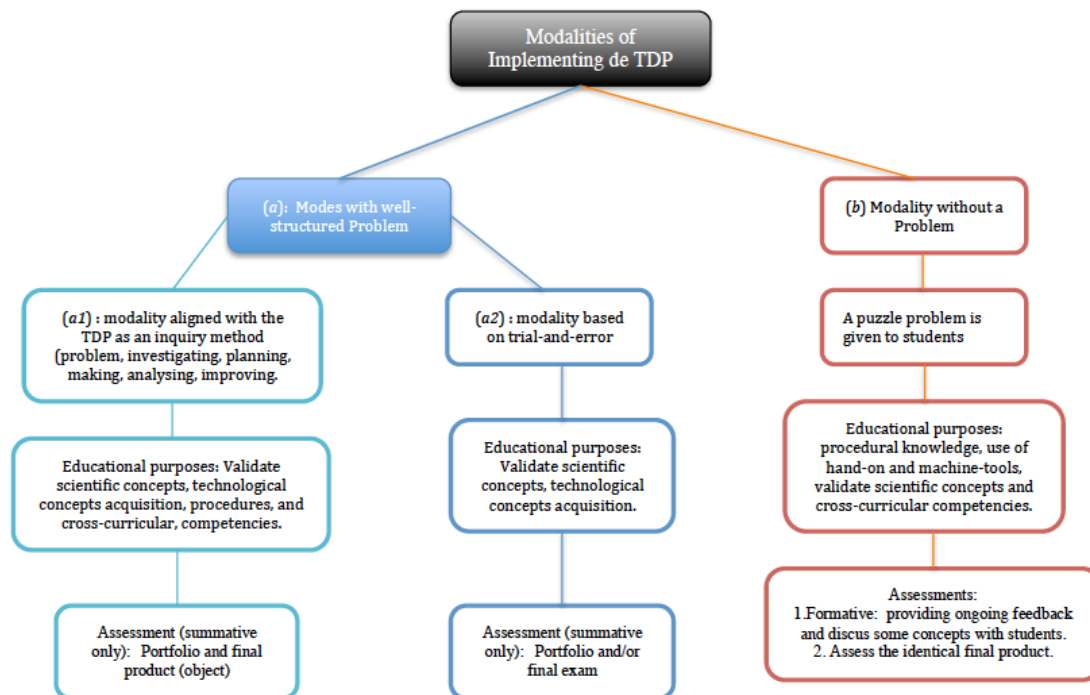
Figure1: Modalities of implementing the TDP

a. Modes including a well-structured problem

Seventeen situations present a *well-defined* problem. These kinds of problems have a definite solution process which requires the application of concepts, rules and principles from a given knowledge domain.

a1. Modality aligned with the inquiry method

The outcomes of our inquiry show that only thirteen situations out of seventeen follow the inquiry method as a process to solve the problem.

In this perspective, the teachers present a problem to their students and ask them to do research in order to understand the problem. During this step, participants require their students to collaborate to elaborate the specifications of the problem, explore possible solutions, choose the best one in regards to the specifications, and to identify materials needed to build the solution. Moreover, they ask students to sketch some views of their objects and they bring them to the working shop to create their designs. In this step, students learn to use machine-tools with the assistance of a lab technician. In the final step, students carry out tests to improve their solution with respect to the specifications.

Regarding the educational purposes, teachers aim to: 1) validate the scientific knowledge learned in previous courses; 2) acquire declarative and procedural knowledge. The first point of view reduces the TDP to applied science. In the second view, which aims mainly procedure knowledge, it appears that the field of technology education has not moved far from its industrial arts roots.

Regarding assessment, we asked participants to tell us what they assessed during the activity. They said that they evaluated the portfolio of the design and the artefact.

Even though the *well-structured* problems seem to be appealing for students, they are good only for checking basic understanding and facts, something that is often the desired outcome of textbook exercises, homework and exams.

a2. Modality focused on trial-and-error

Four situations, among the seventeen discussed above focus on trial-and-error method. This strategy leaves learning to chance. The participants enrolled in this category said that they didn't ask their students to do research nor to plan their design process as shown in the excerpt below.

They [students] went directly to build. I didn't ask them to plan. I could have asked them to plan their activity, such as describe what you are going to do in case of another person wanting to reproduce it. But I did not (Participant 9).

Following the logic of trial-and-error puts teaching the TDP far up the program's expectations. Indeed, according to Quebec Education Program, the TDP is used when a need has been identified. The resulting study of the technological problem must take into account any conditions and constraints in the specifications. The design process, which requires logic, precision, abstraction and execution, enables students to move from the reasoning stage to the practical stage.

b. Modality without a problem

Ten situations discussed by participants present to the students the kind of *puzzle* problem. According to Jonassen (1997), *puzzle* problems are characterized by having a single correct solution, which is arrived at by using a specific suggested procedure. The participants enrolled in this perspective provide not only a problem situation to their students, but also its unique solution. They provided to students the process to follow, all necessary sketches and quoted views. Moreover, they guided the manufacturing through demonstration. In other words, they said that they showed their students the best way to build their artefacts as evidenced in the excerpt below.

We show them the best way to build the wooden poles for their bridges. Anyway, we must guide them. The shape of the poles remains the student's choosing, but how to make them is a teacher's task. (Participant 16)

The participants enrolled in this logic aim at procedural knowledge, the use of hands-on and machine-tools and the development of cross-curricular competencies.
Concerning assessment, participants assess the students' learning in a formative way and give particular attention to the final product, identical artefacts.
In this transmissive perspective, all students follow the same model to make the same artefact. Each team is encouraged to follow the process indicated by the teacher. When a more complex skill is required, the student observes the teacher's demonstration. This logic stifles creativity because students always take the safe option, following the teacher's process, rather than taking risks; whereas the risk is a prerequisite function of creative endeavour.

Challenges faced by teachers

In the specific circumstances of Quebec education, where most ST teachers are untrained in technology, the questions arise concerning what barriers and challenges are facing teachers as they seek to teach engineering design knowledge and processes?
The outcome analysis of the study shows that five challenges were frequently mentioned: (1) managing the students' questions and team working conflicts; (2) problem of equipment; (3) training in technology; (4) student motivation; and (5) workshop and lab technician availability.

The participants discussed the first challenge, team working conflicts, reduce the challenges faced by teachers in its social dimension. The second-ranked challenge is related to the available resources and budgets. In the third ranked challenge, participants pointed out the lack of training in technology education and TDP. The fourth ranked challenge, student motivation, is relates to the psycho-pedagogical dimension. The last challenge is connected to workshop and lab technician problems (school context).

The results of this study indicate a strong need for developing additional professional development opportunities to assist technology teachers in the Quebec context to properly implement TDP in their classrooms.

5. CONCLUSION

The outcomes of our study come from the analysis of how teachers implement the TDP in their classrooms. Three main modalities are met through classroom practices: modality aligned with the inquiry method; modality focussed on trial-and-error; and modality without a problem.

The modality aligned with the inquiry method provides, to some extent, a *well-defined problem*. It didn't prepare students for the real-life where problems are always *ill-structured*. The modality focussed on trial-and-error neglected student endeavors and it reflects a chaotic and limited nature of the knowledge acquisition. In the modality without problem, the participants enrolled in this perspective proceed by guided action. This view ignores the acquisition of technological knowledge.

The results of this study have identified how teachers deal with the implementation of the TDP in their classrooms and the challenges faced by teachers when seeking to implement this process. One strong outcome raised by all participants throughout the interviews regards teacher training and professional development. Indeed, the untrained teachers discussed their lack of understanding technology knowledge and processes. Those trained were aware of their colleague's inability to teach the design process efficiently.

Finally, the results of this study provide an excellent opportunity for Quebec leaders, stakeholders and any other educator seeking to design professional development to be informed about teaching practices, assessment strategies, and identified challenges faced current technology education teachers seeking to implement TDP at the high school level. Information obtained from this inquiry can help professional developers to create workshops, didactical resources, and other support materials that will properly address teacher concerns and equip these educators with the necessary skills and knowledge to properly teach TDP in their classrooms.

REFERENCES

Bardin, L. (2007). *L'analyse de contenu*. Paris: Presses Universitaires de France.

Barlex, D. (2011). Dear Minister, this is why Design and Technology is a very important subjetc in the school curriculum. *Design and Thechnology Education : An international Journal, 16*(3), 9-18.

Borgford-Parnell, J., Deibel, K. & Atman, C.J. (2010). From engineering design research to engineering pedagogy: bringing research results directly to the students. *International Journal of Engineering Education, 26* (4), 748–759.

Cunningham, C.M. & Hester, K. (2007). Engineering is elementary: an engineering and technology curriculum for children. In: *Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition, Honolulu, Hawaii*. Washington DC: American Society for Engineering Education.

Daugherty, J. (2012). *Infusing Engineering Concepts: Teaching Engineering Design*. Purdue University, United-States.

De Vries, M. J. (2005). *Teaching about technology*: *An introduction to the philosophy of technology for non-philosophers.* Dordrecht, The Netherlands : Springer.

Dym, C., Agogino, A., Eris,O., Frey, D., & Leifer, L (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education, 95*(1), 103-120.

El Fadil, B. (2015). High School Technology Design Process - Goals and Challenges. *The International Journal of Arts and Science, 08*(06), 109–116.

English, L-D., Hudson, P-B. & Dawes, L. (2012). Engineering design processes in seventh-grade classrooms: bridging the engineering education gap. *European Journal of Engineering Education, 37*(5), 436–447.

Franske, B-J. (2009). *Engineering problem finding in high school students*. Doctoral dissertation, University of Minnesota, United-States.

Hasni, A., Lenoir, Y. & Froelich, A. (2015). Mandated Interdiscipinarity in Secondary School: The case of Science, Technology and Mathematics Teachers in Quebec. *Issues in Interdisciplinary Studies*, (33), 144-180.

Hasni, A., Lenoir, Y., Larose, F. & Squalli, H. (2012). *Interdisciplinarité et enseignement des sciences, technologie et mathématiques au premier cycle du secondaire : place; modalités de mise en œuvre; contraintes disciplinaires et institutionnelles*. Rapport de recherche, Centre CREAS, Université de Sherbrooke.

Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to learn about complex systems. *Journal of Learning Sciences*, *9*(3), 247-298.

ITEA (2007). *Standards for Technological Literacy – Content for Study of Technology*. International Technology Education Association.

Jonassen, D. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development, 45*(1), 65-94.

Layton, D. (1995). Constructing and reconstructing school technology in England and Wales. *International Journal of Technology and Design Education. 5*(2), 89-118.

Lee, H., & Cho, Y. (2007). Factors affecting problem finding depending on degree of structure of problem situation. *The Journal of Educational Research, 101*(2), 113-124

Potter, P. (2011). Technologists talk: making the links between design, problem-solving and experiences with hard materials. *International Journal of Technology Design Education, 23*, 69-85.

Gouvernement du Québec (2004). *Mathematics, Science and Technology*. Quebec Education Program.

Tate, D., Chandler, J., Fontenot, A. F. & Talkmitt, S. (2010). Matching pedagogical intent with engineering design process models for precollege education. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 24*, 379-395.

Wicklein, R. C. (2006). Five good reason for engineering design as the focus for technology education. *The Technology Teacher, 65*(7), 25-29.

Learning and teacher support material to promote 21st Century skills for junior secondary school students

Werner Engelbrecht
University of Johannesburg
South Africa
E-mail: wernere@uj.ac.za

Abstract

Binkley, Erstad, Herman, Raizen, Ripley and Rumble (2012) identified ten 21st century skills organised into four categories. Technology as a school subject can be used to develop a number of these skills, especially those in the "Ways of thinking" category. Technological procedural knowledge comprises a thinking ("minds-on") dimension which relates to these 21st century skills and an activity ("hands-on") dimension relating to the procedural stages of the technological process. Through the application of the technological process and its associated thinking sub-processes (critical thinking, creative thinking, decision making, problem solving and design) in the technology classroom, students should be exposed to, and be accorded the opportunity to practice these important 21st century skills.

Based on Mitcham's framework (1994), a four-faceted set of criteria for the evaluation of intended technology curricula has been derived from technology classroom pedagogy, technology teacher education, science, technology and society (STS) studies, and classroom pedagogy (Ankiewicz, 2013). Learning and teacher support material (LTSM) for junior secondary school students, consisting of workbooks and teacher guides were developed based on the curriculum. Each workbook that is facilitated over the timeframe of a term includes a mini practical assessment task (PAT) as a capability task that typically includes the design, making and evaluation of a solution to a technological problem. However, the extent to which the LTSM promotes complex thinking has not been evaluated.

The purpose of this paper is to retrospectively investigate the extent to which the LTSM develop 21st century skills and complex thinking in junior secondary school students, guided by the following research question: To what extent does the LTSM provide for the thinking and activity dimensions of technological procedural knowledge? This conceptual paper reports on desktop research in which the LTSM were analysed according to the abovementioned criteria. The analysed workbooks were found to lack some explicit content on the thinking dimension (i.e. 21st century skills) of procedural knowledge, especially in the first few terms.

Keywords: Technology education; Learning and teacher support material; 21st century skills; complex thinking; Technological procedural knowledge.

1. INTRODUCTION

1.1 21ST century skills

Plomp (2013) is of the opinion that "For those living in the information society, professions and personal life have changed fundamentally as compared to living in the industrial society. Given the role of education and schools in the society, we have to ask the question what these changes mean for what young people should learn in school so that they will be optimally prepared for their life in an information society." Binkley et al. (2012) state that "research during the last

158

decade has shown how new social practices evolve due to increased use of new digital technologies, especially among young people." This phenomenon requires us to rethink key skills for the everyday lives of people living in our societies. Problem solving is defined as a key component of living in a modern society, and young people's experiences of it should influence the way we define key skills. The basic knowledge and skills expectations of the past need to be replaced by new standards of what school students should be able to do. To this end, Binkley et al. (2012) identified ten 21st century skills, and organized them into four categories, namely: ways of thinking; ways of working; tools for working; and living in the world.

The skills under the "ways of thinking" category, namely "creativity and innovation" and "critical thinking, problem solving, decision making", relates closely to "critical thinking and problem solving skills" and "creativity and innovation skills" listed under "learning and thinking skills" in the Partnership for 21st Century skills framework as well as the "Critical thinking, Problem Solving, and Decision Making" category in the International Society for Technology in Education ICT Skills framework (Dede, 2010), and will be focussed on for the purpose of this paper.

According to Binkley et al. (2012) these skills represent a more advanced way of conceptualising thinking than the more simple thinking skills such as recall and drawing inferences, and so require greater focus and reflection. It was interesting to note that in the discussion of the three categories of skills under ways of thinking, numerous examples were given of school subjects in which these skills were developed and used, without any mention of Technology education.

1.2Conceptual and procedural technological knowledge

The knowledge of technology comprises conceptual knowledge (knowing *that* knowledge) and procedural knowledge (knowing *how* knowledge). Although there is a distinction between these two types of knowledge they cannot be separated (McCormick, 1997; Ankiewicz, 2013). Procedural knowledge, often referred to as 'tacit knowledge' or 'informal knowledge', is implicit and difficult to build into a curriculum. Design, modelling, problem-solving and system approaches are examples of technological procedural knowledge, which differs from conceptual knowledge in that it cannot be taught but only gained through thorough practice (Ankiewicz, 2013).

Technological procedural knowledge comprises a thinking ("minds-on") dimension and an activity ("hands-on") dimension. The former is related to the development and application of complex thinking and the thinking sub-processes of the technological process, namely, critical thinking, creative thinking, decision-making, problem solving and design (Ankiewicz, 2015). Critical thinking is a process of sifting through information. It involves disciplined conceptualisation, application, analysis, synthesis and evaluation of information gathered through investigation, observation, experience, reflection, reasoning or communication, and then using the results to make progress to a specific end. Creative thinking produces new and unique ideas through application, commitment and perseverance to produce innovative, imaginative, divergent and possibly outrageous ideas to produce new productive solutions to problems.

Although critical and creative thinking are two separate processes, they are both essential aspects of effective thinking and are both needed for making decisions, which involves collecting alternatives (through creative thinking) and evaluating alternatives and finally selecting the most suitable alternative (through critical thinking). The problem solving process depends greatly on a combination of the critical and creative thinking processes, as well as the decision-making process. The process involves identifying a problem and generating possible solutions to the problem. The ides are then analysed and a decision is made on which idea should be pursued. The decision is then carried out and the solution is evaluated. The design process is the

application of the problem solving process involving the development of a solution to a technological problem, and includes all the thinking sub-processes mentioned above (Ankiewicz & De Swardt, 2002).

The complex thinking skills necessary to apply the thinking sub-processes of the technological process mentioned above relate directly to the 21st century skills under the "ways of thinking" mentioned earlier. The skills "creativity and innovation" and "critical thinking, problem solving, decision making" were identified as candidates for promotion by Technology education and through the use of learning and teacher support material (LTSM) as they tie in well with the complex thinking skills that Technology education tries to develop and requires from students in order for them to apply the technological process in a meaningful way.

Technology as a school subject can be used to develop a number of these skills, especially "creativity and innovation" and "critical thinking, problem solving, decision making" in the "ways of thinking" category. Through the application of the technological process and its associated abovementioned thinking sub-processes in the technology classroom, students should be exposed to, and be accorded the opportunity to practice their ways of thinking and the 21st century skills already mentioned.

The activity ("hands-on") dimension or "activity know how" (Jarvinen & Rasinen, 2015) relates to the procedural stages of the technological process (Ankiewicz, 2013). The procedural stages of the technological process are associated with the rational problem-solving paradigm in which a number of procedural stages follow each other in a linear fashion and the one stage needs to be completed before starting with the next one. This problem-solving paradigm is often associated with the way engineers practice technology, and when reflective is a more iterative approach to practicing technology that allows the technologist more freedom. It is often associated with the way architects practice technology (Ankiewicz, 2013).

1.3 Evaluation of the caps in South Africa

Before the Curriculum and Assessment Policy Statement (CAPS) document was implemented as the national curriculum in South Africa, the National Curriculum Statement (NCS) was the only curriculum document. It was less prescriptive with regard to the order of specific content per grade and per term and was largely open for interpretation, which was ideal for experienced teachers who could prepare their own LTSM but problematic for inexperienced and untrained teachers (Engelbrecht et al., 2007). The CAPS was purposefully made more prescriptive in an attempt to synchronise and standardise the content taught and the time spent on each theme. It was much more prescriptive than the NCS in terms of time spent on specific content, to the extent that it has taken the form of a work schedule (DoBE, 2011).

Based on Mitcham's framework (1994), Ankiewicz (2013) derived a four-faceted set of criteria for the evaluation of intended technology curricula from technology classroom pedagogy, technology teacher education, science, technology and society (STS) studies, and classroom pedagogy. The criteria were subsequently used in a critical analysis of the CAPS for technology in junior secondary schools. However, it was found to have certain shortcomings, introducing conceptual knowledge in a fragmented way after which procedural knowledge would be introduced by a mini Practical Assessment Task (PAT) rather than the ideal of using the procedural knowledge and the procedural stages of the technological process as point of departure. The CAPS was found to emphasise conceptual knowledge over procedural knowledge, without putting sufficient emphasis on the close relationship between the two. The limited time allowed for activities in which students could use procedural knowledge was also raised as a concern (Ankiewicz, 2013).

160

Regarding the thinking dimension of the procedural knowledge of technology the CAPS was found to be problematic in that there was no explicit reference to decision-making or design as sub-processes of complex thinking. Nor did it provide for the explicit teaching of these skills before they learners were expected to apply them when going through the procedural stages of the technological process. They require more time to develop the activity dimension or "activity know how" (Jarvinen & Rasinen 2015) of their procedural knowledge. The rational problem-solving paradigm was to be applied for the activity dimension of the procedural knowledge (the mini PAT in each term) with no mention of the reflective paradigm (Ankiewicz, 2013).

1.4 LTSM for technology

In South Africa, Technology education poses certain challenges to teachers, with qualified and experienced ones from other subjects, such as Home Economics, Woodwork, Metalwork and Industrial Arts, typically being assigned to teach it, without any training or orientation regarding its underlying philosophy and objectives, which differ significantly from their old subjects (Engelbrecht et. al., 2007; Engelbrecht & Ankiewicz, 2016). LTSM for technology predominantly comprises textbooks, and those available for Technology education are typically compiled by combining content from Home Economics and Industrial Arts as well as Technical Drawing and other technical subjects. These focus on content and typically ignore the technological process that is the cornerstone of Technology education. Nor do they contain guidelines for students or teachers on how to use the material, a shortcoming which, combined with the typical technology teacher's unfamiliarity with the subject, does not bode well for technology teaching (enacted curriculum) in the classroom (Engelbrecht et. al., 2007).

Based on experience with student teachers, as well as practicing teachers, together with expertise and research, LTSM in the form of workbooks and teacher guides has been developed that complies with the CAPS curriculum in an attempt to assist students and teachers alike. The workbook, in which students complete activities directly rather than as a separate script, was chosen as a format above a typical textbook because Technology is activity based. Hence the procedural stages of the technological process were taken as points of departure for the LTSM.

LTSM have been developed for Grades 8 and 9. The CAPS for junior secondary students covers three grades, 7, 8, and 9, of which grade 7 is physically located at primary school. Prior to Grade 7 technology is combined with natural science, with little attention given to Technology. When students reach Grade 8 in the junior secondary school, it is often their first experience of Technology as a separate subject, making the Grade 8 LTSM key. Based on this shortcoming, for the purpose of this paper, the focus will be on the Grade 8 workbooks. They are structured according to the various learner tasks, including resource tasks, capability tasks as well as case studies and/or a stage or a grouping of procedural stages of the technological process (Ankiewicz et. al., 2005). All the activities are assessed by means of included self, peer and teacher assessment sheets. The way in which students document their work in the workbook as they proceed through the stages of the process also make the completed workbook useful as a significant part of a design portfolio.

Written to comply with the intended curriculum, i.e., the NCS and the CAPS, the LTSM was developed prior to the critical analysis of the CAPS and thus before all the shortcomings were known. With these identified in the CAPS, the assumption is that the LTSM developed for school students might suffer from similar shortcomings.

Each workbook that is facilitated over the timeframe of a term includes a mini PAT as a capability task that typically includes the design, making and evaluation of a solution to a technological

problem, however, the extent to which the LTSM promotes complex thinking has not been evaluated.

The purpose of this paper is to retrospectively investigate the extent to which the LTSM develop 21st century skills and complex thinking in junior secondary school students, guided by the following research question: To what extent does the LTSM provide for the thinking and activity dimensions of technological procedural knowledge?

This conceptual paper reports on desktop research in which the criteria for the evaluation of the intended technology curricula developed by Ankiewicz (2013) were used to evaluate the workbooks. Although developed to critically analyse the intended curriculum of technology (CAPS) they were refined from criteria for classroom pedagogy and teacher training. These aspects are so closely related to LTSM that it seemed appropriate also to apply the criteria to the LTSM developed for school students (as part of the enacted curriculum). As mentioned above, the shortcomings of the CAPS were unknown at the time when the LTSM was developed, so it is evaluated retrospectively.

2. **FINDINGS**

The codes used in the findings, e.g., (E1 and M1) and (V2), refer to the relating criteria. Both conceptual knowledge (e.g., Appendix 1, Figure 1) and procedural knowledge (e.g., Appendix 2, Figure 2) are included in all the workbooks. Students are typically exposed to conceptual knowledge (e.g., Appendix 1, Figure 1) regarding one or more of the themes of technology (dictated by the intended curriculum). Students are expected to apply the technological process (e.g., Appendix 2, Figure 2) to solve problems through identifying a problem, designing a solution and making as well as evaluating the solution, thus applying the procedural knowledge (and methodology) of technology (E1 and M1).

The workbooks include conceptual knowledge of technological artefacts (E2) and both types of knowledge, however, there is a wider focus on conceptual knowledge than procedural knowledge dictated by the CAPS. The workbooks have been written with technological procedural knowledge as a point of departure which enhances the balance between conceptual and procedural knowledge (E3) (refer to Figures 1 and 2). The relationship between the two is constantly emphasised in the workbooks. Although procedural knowledge is taken as a point of departure, conceptual knowledge required to be applied during the procedural stages is imported into some of the stages, typically investigation (E4) (Refer to Figures 2 and 3).

The conceptual knowledge contained in the workbooks includes knowledge unique to technology (e.g., gears in Figure 1) as well as knowledge from subjects such as science (e.g., electricity in Figure 4) and mathematics (E5). The workbooks also accord students the opportunity to practice working through the technological process (Refer to Figures 2 and 3) at least once per term, and in some cases twice (E6). The workbooks had to be written to comply with the highly prescriptive curriculum (CAPS), and as such could not often introduce the procedural knowledge (technological process) from the start of a term. In some cases, however, the project brief was moved to earlier in the term than specified to accomplish the contextualisation of the conceptual knowledge (E7).

The thinking dimension of the procedural knowledge of technology is not taught explicitly to students in the workbooks. The steps of creative thinking, critical thinking, decision-making, problem-solving and design (the thinking sub processes of the technological process) are not explicitly taught to students. Nor are activities included in the workbooks with the specific purpose of practicing these processes separately. The workbooks do include activities in which

162

students are expected to apply one or more of these processes in the form of resource tasks, when they have to think analytically and solve problems (refer to Figures 1, 3 and 4). The thinking sub-processes are thus implicitly included in the workbooks.

The rational problem-solving paradigm (Figures 2 and 3) is explicitly used in the workbooks as an organisational framework and is used at least once in every term to provide students with an opportunity to develop their procedural knowledge through practice (M1). Because the rational problem-solving paradigm is explicitly used in the workbooks, and the curriculum is prescriptive, students are provided with little opportunity for reflective design (M2). The workbooks are activity based (Figures 1-4) in their entirety and accord students ample opportunity to practice it (M3). Although they are not explicitly taught creative and critical thinking, decision-making, problem-solving or design as sub-processes of complex thinking due to the prescriptive curriculum and time constraints, they are, however, accorded ample opportunity (Figures 1 and 3) to practice these skills implicitly and progressively from Grade 8 term 1 to Grade 9 Term 4 (M4 and V2).

3. **DISCUSSION AND CONCLUSION**

Regarding the thinking dimension of procedural knowledge, the workbooks require more explicit teaching of the thinking sub-processes, especially during the first several terms, to familiarise students before they are expected to apply them when going through the process. Once they have been initially taught about the thinking sub-processes (e.g., the steps of the different sub-processes) explicitly, they are accorded sufficient opportunities to practice them through applying the technological process at least once per term throughout Grades 8 and 9.

The 21st century skills associated with the category "ways of thinking" are promoted implicitly to a large extent by the workbooks. Creativity and innovation are encouraged and promoted by the very nature of the technological process that the students work through at least once per term. During each term students are expected to identify, a problem, design a solution, make the solution and evaluate it. Creativity is key in both identifying the problem, as well as coming up with possible solutions for the problem in the form of freehand sketches during the initial ideas stage.

The workbooks are activity-based and as such accord students ample opportunity to develop the activity dimension of their procedural knowledge. Students complete the activities directly in the spaces provided in the workbook, which enhances the engagement with the activity dimension of the procedural knowledge. The workbooks provide students with ample opportunities to practice the procedural stages (activity dimension) of the technological process. The thinking sub-processes (thinking dimension) associated with technological procedural knowledge, relating to the "way of thinking" 21st century skills, are however only taught implicitly through the activities included in the workbooks. Critical thinking, problem-solving, decision-making and design are prerequisites for considering all the aspects of a project brief and sifting through the information to distil the problem. Similarly, critical thinking is required to weigh different ideas and possible solutions, developed through being creative, and thus identifying the most appropriate solution. By practicing the technological process every term, the skill of "learning to learn" or metacognition is also developed in that students are given the tools to solve everyday problems through the thinking sub-processes.

The analysed workbooks were found to lack some explicit content on the thinking dimension of procedural knowledge, especially in the first few terms. This is not surprising considering the strict prescriptions of the CAPS used to compile the LTSM. Writers of LTSM should ensure that both conceptual as well as procedural knowledge, especially complex thinking as 21st century skills, are

included in the LTSM. The one type of knowledge should not be over-emphasised at the cost of the other. Lastly, the writers of LTSM should provide for the direct teaching of complex thinking as so-called 'enabling tasks' before students are expected to apply these thinking skills and sub-processes in subsequent activities. The criteria for the evaluation of the intended technology curricula might assist writers of LTSM to mediate complex thinking as part of 21st century skills.

Bibliography

Ankiewicz, P.J. (2013). 'n Teoretiese besinning oor die implikasies van die filosofie van tegnologie vir onderwyseropleiding. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie,* 32(1), Art.#386, 9 pages. http://dx.doi.org/10.4102/satnt.v32i1.386.

Ankiewicz, P.J. (2015). Inheemse en Westerse tegnologiese kennisstelsels: Twee kante van dieselfde muntstuk?, *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie* 34(1), Art. #1309, 7 pages. http://dx.doi.org/10.4102/satnt.v34i1.1309.

Ankiewicz, P.J. & De Swardt, A.E., 2002, 'Aspects to be taken into account when compiling a learning programme to support effective facilitation of technology education', *National Conference for Technology Teachers proceedings*, Port Natal School, Durban, South Africa, 30 September – 01 October, 2002, pp. 76–81.

Ankiewicz, P.J., De Swardt, E., & Engelbrecht, W. (2005). Technology education in South Africa since 1998: a shift from contents (conceptual knowledge) to process-based learning programmes. PATT 15 conference, Amsterdam, Netherlands. April 2005.

Ankiewicz, P., De Swardt, E., & Engelbrecht, W., (2013a). Grade 8 Term 3 Mechanical systems and control learner workbook. Johannesburg: University of Johannesburg.

Ankiewicz, P., De Swardt, E., & Engelbrecht, W., (2013b). Grade 8 Term 2 Impact of technology learner workbook. Johannesburg: University of Johannesburg.

Ankiewicz, P., De Swardt, E., & Engelbrecht, W., (2013c). Grade 9 Term 1 Stuctures learner workbook. Johannesburg: University of Johannesburg.

Ankiewicz, P., De Swardt, E., & Engelbrecht, W., (2013d). Grade 8 Term 4 Electrical systems and control learner workbook. Johannesburg: University of Johannesburg.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining twenty-first century skills. In Griffin, P., Care, E., & McGaw, B. Assessment and teaching of 21st century skills, Dordrecht, Springer.

Dede, C. (2010). Comparing frameworks for 21st century skills. *21st century skills: Rethinking how students learn*, *20*, 51-76.

Department of Basic Education (DoBE). (2011). *Curriculum and Assessment Policy Statement (CAPS): Technology Grade 7, 8 9.* Pretoria: Department of Basic Education.

Engelbrecht, W., & Ankiewicz, P. (2016). Criteria for continuing professional development of technology teachers' professional knowledge: a theoretical perspective. *International Journal of Technology and Design Education*, 26, 259-284.

Engelbrecht, W., Ankiewicz, P., & De Swardt, E. (2007). An industry-sponsored, school-focused model for continuing professional development of technology teachers. *South African Journal of Education*, 27, 579–595.

Jarvinen, E.M., Rasinen, A. (2015) Implementing technology education in Finnish general education schools: studying the cross-curricular theme 'Human being and technology'. *International Journal of Technology and Design Education*, 25(1), 67-84.

McCormick, R. (1997). Conceptual and Procedural Knowledge. *International Journal of Technology and Design Education*, 7, 141-159.

Mitcham, C. (1994). *Thinking through Technology*. Chicago: The University of Chicago Press.

Plomp, T. (2013). Preparing education for the information society: the need for new knowledge and skills. *International Journal of Social Media and Interactive Learning Environments*, *1*(1), 3-18.

Appendix 1

ACTIVITY 2.1   GEAR SYSTEMS
(Resource task)

INDIVIDUAL

Read the information on gear systems in the next section carefully, and answer the questions that follow on your own.

Seen below are illustrations that represent gears that are connected in various ways. In each illustration the direction of rotation of one gear is indicated by an arrow. You must indicate the direction of rotation by inserting arrows at all the gears.

1.   2.

Driver   Driven   Driver   Idler   Driven

_____ (1)   _____ (2)

3.

Driven gear _____

Intermediate gear I_1 _____

Intermediate gear I_2 _____

Driver gear _____
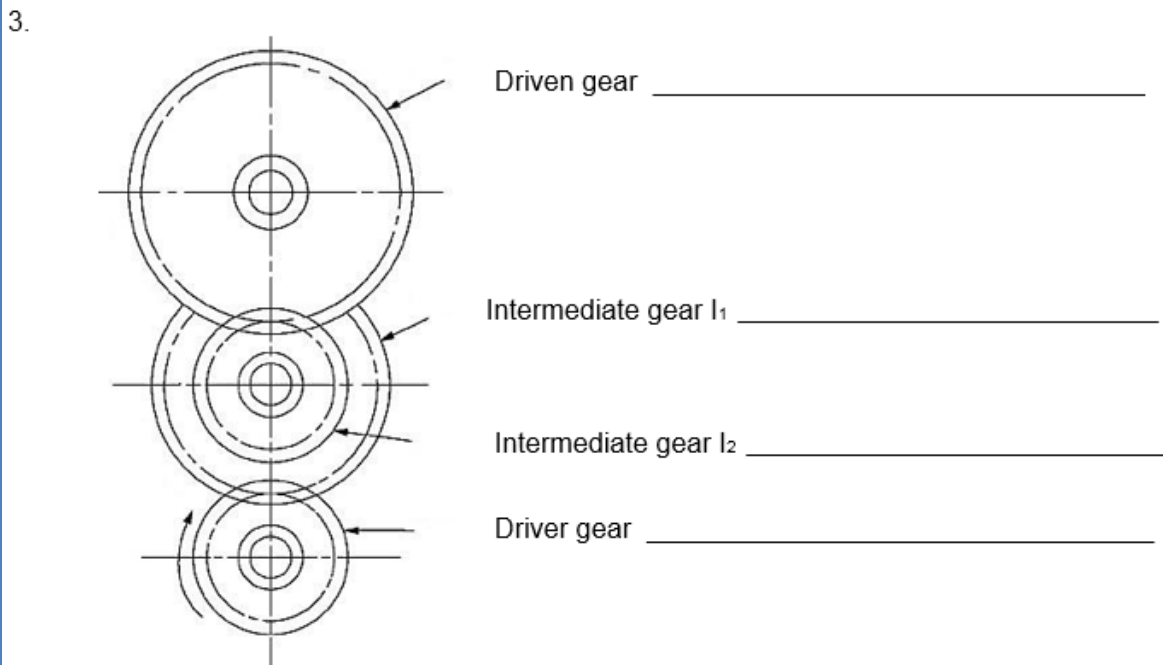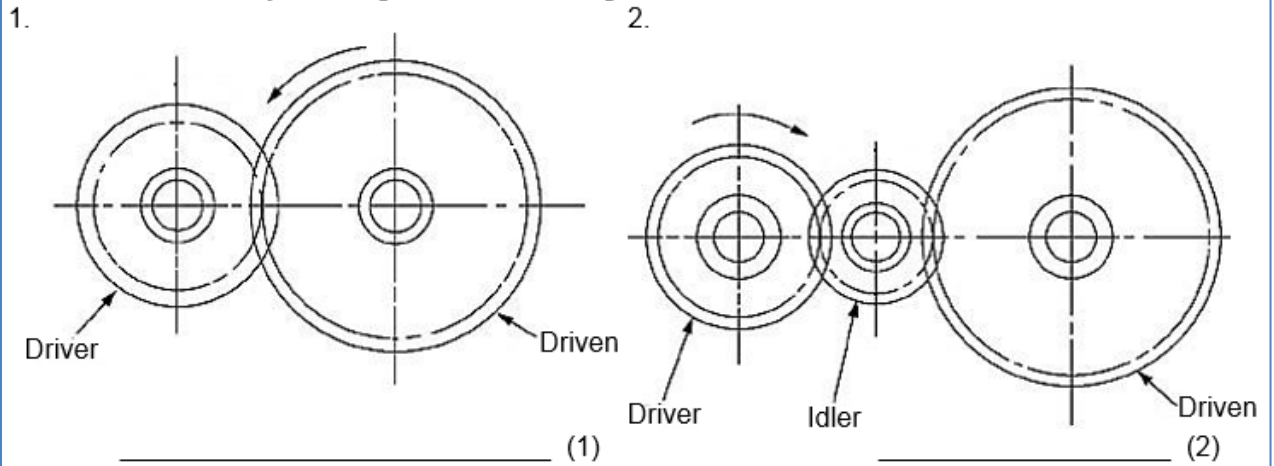
(3)

Assessment of Activity 2.1: After you have answered all the questions, your teacher will discuss the questions with you and give you the correct answers. Assess your own answers and add the number of correct answers to get a mark out of 6.

Note: The assessment mark must be carried forward to the report card on page 63.

Mark: /6

Figure 1: Excerpt as example of technological conceptual knowledge of gears and implicit analytical thinking (Ankiewicz et al., 2013a).

Appendix 2

ACTIVITY 6.1
(Capability task)

DESIGNING A SOLUTION TO REDUCE THE
NEGATIVE IMPACT OF TECHNOLOGY

GROUP WORK

Read the information in the next section carefully on your own, and answer the questions that follow.

Project brief
You are an engineer for a company whose focus is green technology. You have been given the order to work together as a team of three engineers to design a new product that would solve the problem of negative effects of technology on the environment or would reduce the impact of negative effects of technology on the environment. You now have the chance to change the world of technology to be more environmentally friendly.

You have the following materials and tools at your disposal:

MATERIAL	TOOLS
• Cardboard • Various recyclable plastic products and containers • Recyclable wood	• Utility knife • Safety ruler • Pencil • Ruler • Eraser • Rubber mat • Scissors • Back saw • Bench hook

Answer the following questions to assist you with your task:

1. What is meant by green technology?
   _____
   _____

2. State three possible problems in your surroundings that can be classified as negative effects of technology.
   _____
   _____

You are now ready to start with the capability task. Choose from the list above the problem that your team would like to solve.

Problem statement: State in your own words what the problem is that needs to be solved.
_____
_____

Design brief: Divide into groups of three. Discuss the project brief and problem statement and formulate a short but comprehensive sentence (not more than two lines) about how you intend to solve the problem.
_____
_____
_____

Investigation: Discuss what relevant information each member of the group would need to execute the task at the hand of the particular member's design brief. State the information relevant to your own design brief in the space provided.
_____
_____
_____

Figure 2: Excerpt as example of technological procedural stages (Ankiewicz et al., 2013b)
Appendix 3

1. After you have studied Figure 11, write a **design brief** for the stated problem:
   _____
   _____

2. **Investigation**: Case study of a real flight of stairs and wheelchair ramp

Study the following plan of the specifications of a wheelchair ramp. Based on this information, you must complete the activities that follow.

Specifications for a wheelchair ramp
Ramp slopes between 1:16 and 1:20 (refer to Figure 11) are preferred. The ability to manage an incline is related to both its slope and its length. Wheelchair users with disabilities affecting their arms or with low stamina have serious difficulty using inclines. Most people can manage a slope of 1:16 whether they are walking or using a wheelchair. This means that for 1m the ramp rises in height, it needs to be 16m in length.
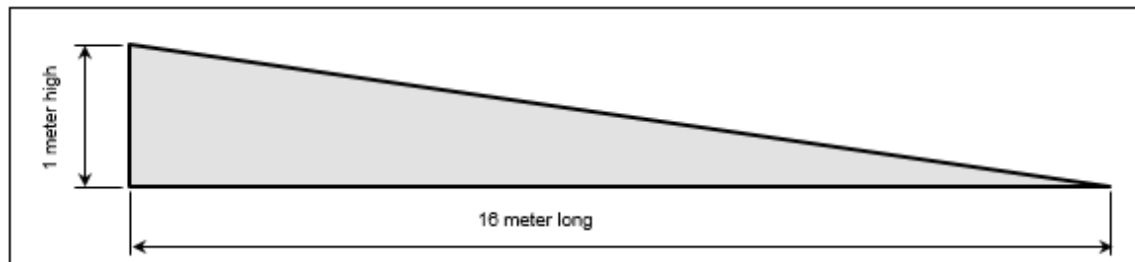
Figure 13: Wheelchair ramp with a slope of 1:16.

Therefore, to build a ramp according to wheelchair ramp specifications, the least possible slope shall be used for any ramp. The maximum slope of a ramp in a new construction should be 1:12. The minimum clear width of a ramp should be 915mm to comfortably accommodate a wheelchair. Keep these specifications in mind when designing your wheelchair ramp.

Find pictures or photographs of a wheelchair ramp and staircase combinations and paste it into the spaces below. After completion, you must answer the questions underneath each picture or photograph you have provided.

Example 1	Example 2

1. How wide is a wheelchair? _____
2. How wide is the ramp? _____   How wide is the ramp? _____
3. How high is the hand rail? _____   How high is the hand rail? _____
4. Does the slope look manageable for a wheelchair user?
   Example 1:_____   Example 2: _____
5. Reflect on the wheelchair ramp and staircase combinations you researched and briefly report on the advantages and disadvantages of each according to your opinion.
   _____

Proposal: Make a list of the specifications or requirements of your design.
Slope of the ramp

Figure 3: Excerpt as example of conceptual knowledge applied in a procedural stage

(Ankiewicz et al., 2013c).
Appendix 4

ACTIVITY 3.3   **SERIES AND PARALLEL BATTERIES**   INDIVIDUAL
(Resource task)

Read the information in the next section on your own carefully and answer the questions that follow.

Each connecting configuration has its own advantages and disadvantages which will be discussed and summarised for you later in this activity.

Cells in series
Connecting cells in series will not increase the maximum current the battery can deliver, but will increase the total potential difference of the battery. In other words the potential difference increases, but the total current the battery can deliver stays the same as that of a single cell. A typical example of such a connection is a torch. Figure 25 explains illustrates such a configuration.
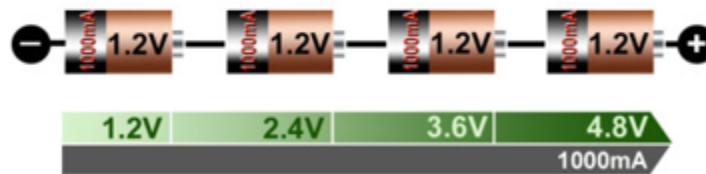
Figure 25: Cells in series

Each cell has a potential difference of 1,2V and can deliver 1 000mA. As you connect these cells in series, the total potential difference of the battery increases, but the battery can still only deliver 1 000mA (1A).

Battery capacity
The capacity of a battery gives an indication of how long it can deliver a certain current before being discharged or "flat". A rule of thumb is that a physically larger cell will have a greater capacity than a smaller cell using the same chemistry. This is because a larger cell has larger electrodes or plates, and more electrolytes, so the chemical reaction will last longer. The capacity of a battery is expressed in ampere-hours (Ah) and is calculated by 20 hours multiplied by the constant current that a new battery can supply for that time. For example, a battery rated at 100A.h will deliver 5A over a 20 hour period. However, if the battery is discharged at a higher rate, say 50A, it will have a lower capacity; in other words it will be flat before two hours have passed.

Complete the following exercise by determining the total potential difference and capacity of the battery configuration in each case.

1.

6 volt
225A.h

6 volt
225A.h

Total potential difference: _____

Total capacity: _____
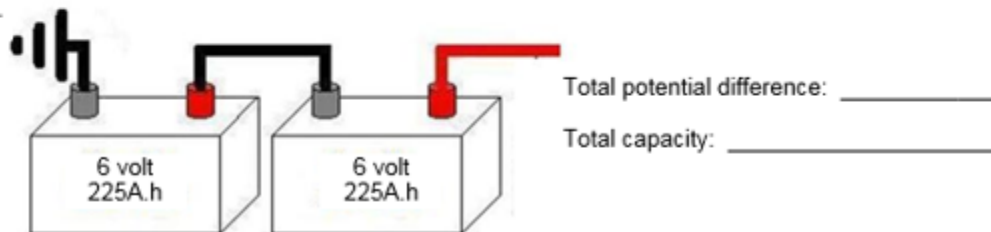
Figure 4: Excerpt as example of conceptual knowledge from science and implicit analytical thinking (Ankiewicz et al., 2013d).

Technology teachers' views on general pedagogical knowledge

Birgit Fahrman
KTH Royal Institute of Technology
ECE, School of Education and Communications in Engineering Science
Sweden
birgitf@kth.se

Lena Gumaelius
KTH Royal Institute of Technology
Sweden
lenagu@kth.se

Summary

Successful teaching and learning require teachers to have knowledge in many different fields and therefore the understanding of teachers' knowledgebase is of interest. In Sweden the debate about the role of teachers and teachers' knowledgebase has been ongoing for some years. This study focus to further develop the understanding of teachers' views about their own teaching in the subject technology, i.e. the content and role the subject take in different school activities. This paper will specifically focus on teachers' description of their technology teaching in terms of teachers' general pedagogical knowledge.

General Pedagogical Knowledge (GPK) refers to skills related to teaching. These skills defined by Grossman (1990) looks at *1) knowledge and beliefs concerning learning and learners*, and *2) knowledge of general principles of instructions*. Also *3) knowledge and skills related to classroom management* and *4) knowledge and beliefs about the aims and purpose of education* are considered general pedagogical knowledge.

The study was conducted by interviewing four teachers about how they teach and about the content of their teaching. They teach at the compulsory school, years 7–9 (pupils aged 13–16). The teachers are all educated as technology teachers, but they have different backgrounds.

Within the 4 subgroups in GPK the teachers' express views mostly concerning principles of instruction, that is methods used in teaching technology and how lessons are structured and planned. Results show that there are a strong tradition in building and constructing. The respondents describe problem and solution-solving abilities and learn how to work with the product development process to specific for the subject.

Keyword: technology teaching, teachers' views, general pedagogical knowledge,

Introduction

Successful teaching and learning requires knowledge in many different fields. Since the teacher has a central role in this process and as the content of what the students learn much depends on the teachers' knowledges and skill, it is of interest to understand more about how teachers express this knowledge.

In Sweden, the debate about the role of the teacher and the teachers knowledgebase regarding the subject technology has been rather intense during the last years which has created an interest for this area, and therefore the intention of the study is to further develop the understanding of teachers' views about their own teaching in the subject technology, i.e. the content and role the subject take in different school activities.

Since the 1980s, when Shulman (1986, 1987) presented a model to categorize the knowledge bases that teachers should possess, researchers have developed and described this theoretical model from many different angles. Often researchers explore specific parts of these knowledge bases in

170

connection to a specific subject, in relation to teachers' profession or to students learning in relation to one particular knowledge base (Ball et al., 2008; Ellis, 2007; Leach & Moon, 2000; Grossman & Richert, 1988; Gess-Newsome, 1999; Jones & Moreland, 2004). Shulmans theories of teacher knowledges looked at various logical components of the knowledge bases for teaching and divided the theory into different areas, such as Subject Matter Knowledge, Knowledge of Context, Pedagogical Knowledge and Pedagogical Content Knowledge (PCK). PCK is probably the area mostly researched over the years.

The theoretical framework applied on this study uses Grossman (1990) "model of teacher knowledge" as a theoretical lens for analysis of the research data collected by interviewing technology teachers in lower secondary school in Sweden. This paper will specifically focus on teachers' description of their technology teaching in terms of teachers' general pedagogical knowledge.

Main question this paper address is:
What can general pedagogical knowledge describe and explain about experienced technology teachers' perception of their teaching in technology?

As the analyzing process is still ongoing results are preliminary.

Background
Technology is a mandatory subject in Sweden and was introduced in the curriculum of 1980. The curriculum was revised 1994 and again in 2011. The subject has been described as somewhat problematic, due to difficulties in defining the subjects' content and place in the compulsory school. It was, and still is, closely linked with the science subjects. With the last revision in 2011 (Lgr11) the characteristics of subject become much clearer, the core content is more detailed and the abilities the student are expected to develop further expressed (Norström, 2014).

In Swedish schools there is a huge lack of subject-specific trained technology teachers. The national center for technology (*Cetis*) published a study in 2012 stating that 50% of those who teach technology are not formally qualified to do so (Teknikföretagen & Cetis, 2012). Many studies also report about differences between qualified and non-qualified teachers, stating that non-qualified teachers to a larger extent lack some of the necessary competences for teaching (Hartell et al., 2014). Many technology teachers do not follow the directions outlined in the curriculum (School Inspectorate, 2014) The situation with teacher shortage is helped to a certain degree by re-education of persons from other professionals, such as engineers and scientist, who study to complement their earlier exam with a teacher degree. Most Swedish technology teachers in lower secondary school do not only teach technology but also mathematics or one or more of the sciences subjects.

In this study we will study qualified technology teachers with long experience in order to find out what this group find to be most relevant for good technology education.

Method
General Pedagogical Knowledge
Grossman (1990) defined the knowledge bases for teaching and there interrelationships as "four general areas of teacher knowledge…as the cornerstones of emerging work on professional knowledge for teaching: *general pedagogical knowledge, subject matter knowledge, pedagogical content knowledge* and *knowledge of context*" (p.5).

This paper specifically use Grossmans knowledge base, General Pedagogical Knowledge, GPK, to analysis how the participating technology teachers' view their teaching. According to Shulman (1987) GPK involves "broad principles and strategies of classroom management and organization that appear to transcend subject matter" (p. 8), as well as knowledge about learners and learning, assessment, and educational contexts and purposes. Also Grossman and Richert (1988) stated

that GPK "includes knowledge of theories of learning and general principles of instruction, an understanding of the various philosophies of education, general knowledge about learners, and knowledge of the principles and techniques of classroom management" (p. 54). A literature review by König et al. (2011) revealed that two tasks of teaching are regarded as core tasks in almost all countries: instruction and classroom management. Generic theories and methods of instruction and learning, as well as of classroom management, can therefore be defined as essential parts of GPK.

General pedagogical knowledge refers to skills related to teaching. These skills defined by Grossman (1990) are: *1) knowledge and beliefs concerning learning and learners*, and *2) knowledge of general principles of instructions*. Also *3) knowledge and skills related to classroom management* and *4) knowledge and beliefs about the aims and purpose of education* are considered general pedagogical knowledge.

The four subcategories of GPK applied on the data material where coded according to:

1) Knowledge and beliefs concerning learning and learners. This can include the teachers' views about areas concerning structure of teaching and learning objectives and strategies of handling learners in general.

2) Knowledge of general principles of instructions. This area includes the teachers' views about preparing, structure and evaluating lessons and the use of a wide range of teaching methods. Grossman describe that academic learning time (that is the amount of time during which students are actively, successfully, and productively engaged in learning (Fisher & Berliner, 1985)), wait time or small group instruction also is included.

3) Knowledge and skills related to classroom management. This includes teachers' strategies concerning to motivate and support student learning as well as to manage the classroom.

4) Knowledge and beliefs about the aims and purpose of education. Within this subgroup different ways of assessment is included.

<u>Respondents</u>

The study was conducted by interviewing four teachers about how they teach and about the content of their teaching. They teach at the compulsory school, years 7–9 (pupils aged 13–16). The teachers are all educated as technology teachers, but they have different backgrounds.

The respondents

Name (not real)	Gender	Subjects and educational background
Adam	M	M.Sc. in Engineering, Qualified to teach mathematics, physics, chemistry, biology and technology. Teacher for 13 years in all subjects.
Bertil	M	Qualified to teach crafts, and technology. Teacher for 27 years, 9 years technology teacher.
Cesar	M	Qualified to teach mathematics, physics, chemistry, biology and technology. Teach in a school where majority of pupils have Swedish as their second language. Teacher for 16 years in all subjects.
Dagny	F	Qualified to teach physics, mathematics, and technology. Teacher for 16 years in all subjects.

All respondents have, to varying degrees, participated in "Boost for Technology" (*Tekniklyftet*), a school development program hosted by the House of Science. This school development program intended to boost the subject Technology in Swedish compulsory schools in Stockholm. Teachers

who participated had over a 2 ½ - year period taken part in seminars, workshops, lectures, etc. on the subject of technology. They had discussed, planned and written their own schools' plans for working with the subject and how it should be taught. By choosing this group of teachers the study would reach teachers with extraordinary experience in teaching technology in lower secondary school.

The respondents are experienced teachers in teaching technology (Hattie, 2003) as they are licensed technology teachers and have been teaching technology for a number of years. In addition to this they have all attended a two year technology-specific teacher development program "Boost for technology" (*Tekniklyftet*).

Data collecting and analysis

The interviews were semi-structured in nature, and approximately followed a questionnaire with follow-up questions for clarification. The analyze process includes multiple readings of transcripts and material was encoded with the help of the subgroups contained in GPK. The analysis focus on what the respondents view as important and special in teaching and learning technology within the GPK. This includes how they plan and execute their lessons, their choice of methods, classroom management and aim of education.

The study follows the ethical rules imposed by the Swedish Ethical Review Act (2003).

Result

Results presented here show how the respondents and their teaching describe GPK in technology education. Several of the categories in the GPK are general and applicable in any subject, here are described those findings that the respondents emphasize are important to their technology teaching outcome.

Knowledge of theories of learning and learners

This knowledge field is less described by the teachers as knowledge of learning and learners is to a large extent general for all subjects and interview questions did not specifically emphases this.

The respondents express their concern about pupils' ability to understand the subject and how they then need to plan their technology lessons according to these needs. Cesar talks of how he guides the pupils and describes his teaching as tight:

"Clear information and not to huge tasks. I don't let them free, I hold the group together, so we do the same thing, those who are ready will help those who are not ready" (Cesar)

The pupils Cesar teaches need much support with the Swedish language:

"Yes, and I work a lot with words, vocabulary or vocabulary concept, it is present in nearly every lesson in all of my groups … As for words and concepts registers, it is necessary for it to work. The words that I take for granted that they understand they're far from it, that's right. We have a blog where we put up, where I put up 5-6 words and says "this you will know to Friday," can be anything, as it turns out, that pop up during the talks, during the lesson, in the talks and written up on the blackboard during the lesson and go really quickly add up and check in." (Cesar)

The teachers describe their technology teaching to be different compared to other subjects. They speak of themselves as coaches and two of they say the teachers' role in technology teaching is easier than teaching other subjects.

Knowledge of general principles of instruction

Respondents describe their teaching combine practical and theoretical elements when conducting technology lessons. They talk of methods in technology classroom to be more problem and solution-oriented.

"Practical work in technology, it is more about solving a problem. In other subjects maybe more about making, but in technology, it is more solution-oriented."(Dagny)

Respondents' use of hands-on work differs in the amount of time spent. Dagny estimated that 70% of the available time was spent constructing and building. Bertil described how everything can be learned through building things. He describes his teaching being mostly "practical," i.e., oriented towards designing and making. Adam spends less than 50% of his time in practical activities. Cesar estimates that 70% of his teaching in technology is practical and expresses:

"At this school, the theoretical part disappears into the practical part. It will be very much hands-on job, if you work with materials you have to have materials there to be able to feel and squeeze. It makes no sense to lecture on various material types and plastics and stuff. It runs together more here. Don't think I put a label on what we do. I say today we will do this, and if it is, say try and make a craft float for two minutes and then sink, we are first in the theory and then tries to practically implement, operate and test and improve their solutions. They are probably related; they belong together."(Cesar)

All respondent participate or have participated in competitions like First Lego League (FLL) and Future City. Dagny and Bertil say that much of the core content is covered by participating. Cesar say he use the concept of FLL with his pupils groups, but choose not to participate in the real competition. Instead, the school conducts its own competition designed to better suit the pupils groups.

Three of them also teach science. In science subject an investigative approach that test theory during one lesson is usual but is only used to a limited extend when teaching technology. Dagny and Adam each mention one short activity in technology class during which they test hypotheses in an experiment. Cesar speaks of how he connects activities in technology with activities he does within the science class.

Knowledge of the principles and techniques of classroom management
The respondents plan project that take several weeks to complete when teaching technology and organize pupils work in classroom according to the content of the project. Adam says he seldom uses groups in class as he feels that both assessment of group work and pupils involvement in group work is difficult.

"Group work … it could sometimes tend to be too much play when it is team work and pupils keep on with other things." (Adam)

Dagny and Cesar say they mostly work with small groups of 2-4 pupils. Dagny says:

"We have 22-24 pupils in class and tend to divide them into different sized groups depending on the material to be used or what we should do. In ninth grade, they work always two or alone, in the robot group (FLL) in grade 9 are the four in each group. Should we build a city, it is actually the whole class."(Dagny)

Practical activities are mentioned by all respondent as a way to engage and motivate students involvement and also because pupils enjoys working practical. Adam says:

"Yes, it is a student engagement, almost all students find it very enjoyable, they become very involved, especially when they have been doing their own stuff and they get that "flow". The

teacher is almost not required; one can observe the pupils, to help them in another way. When one comes across that border, it's very fun and rewarding to teach technology." (Adam)

Knowledge and beliefs about the aims and purpose of education
Cesar describe the aim with his technology teaching has to be adjusted to the student group he teaches. He makes sure the student have worked with the different abilities they are to develop but says that he cannot teach the whole core content. Also the other respondents speak of planning their teaching in order to connect to the learning objectives and core content but express not having enough time to do everything in the core content. Bertil says:

"I make sure that tasks are such that the elements in the core content are included, or part of, I do not have time to do everything. It is only to realize, but I try to get as many parts as possible and then I choose tasks on that basis." (Bertil)

All of the respondents talks of assessing their pupils' work formative, as they walk around looking at their pupils and in the discussion they have with them. Bertil describe:

"I have all the time, or trying to be, these five bullet points [technological abilities, specified in Lgr 11] *in the head and trying to set them in relation to the knowledge and in each, my assessment is all the time in discussion with the student - what is happening here, what did you do now, how do you get on, where are we going?" (Bertil)*

They all mention that when they have one-to-one discussions with a pupil or pupil group they hear and see if the pupil understands the contents. Most of them use reports and presentations as summative processes. Two of the respondents use written tests in order to check the pupils' knowledge.

The on-going analyzing process will also give answers to if the teachers see similar issues as important for their GPK, and it will also give a more quantitative answer on how much the respondents express the different competences.

Discussion

Within the subgroups in GPK the teachers' express views mostly concerning methods used in teaching technology and how lessons are structured and planned (cf. principles of instructions). Also, the issue on how to motivate pupils is important for teachers to bring up (cf. classroom management).

The tradition in the subject to work with hands-on activities during technology lessons is strong. The respondents teaching is based largely on building and constructing (student mostly build different models). Participating in competition, like FLL and Future City, also include building and constructing. Findings in this study indicate that practical activities outweigh theory. The teachers say they seldom use short hands-on activities during one lesson (as they do in science class). At the same time the respondents talk of not having enough time to work with the complete core content and therefor exclude some parts. As general principles of instructions include use of a variety of teaching methods, it seems like technology teaching is fixed using certain methods in technology classroom and that the respondents are not reflecting on different methods to work with in order to include the whole curriculum. If methods of teaching technology not are questioned and instead taken for granted, it may hinder further development of teaching in the subject.

On the other hand hands-on activities as a method is important both as part of the technology subject and important as a specific knowledge practice. To work practical in projects that take several weeks in executing is not uncommon or strange in technology education. As the subject in Sweden often is scheduled for one lesson per week, projects often take up half of a semester or more. Even in booklets published by the National Board of Education (Skolverket, 2011) there are materials to help teachers plan projects which span over several weeks. When building and constructing, the teachers say pupils develops problem and solution-solving abilities and learn how to work with the product development process. The teachers mean this is especially important to focus on for technology education. But a prerequisite for establishing a knowledge

practices around practical activities is that teachers have access to tools in the form of knowledge of subject-specific knowledge and are able to convert the knowledge into practices in the classroom that evolve student learning (Carlgren, 2015). The respondents' show differences in the amount of time they spend on practical activities and how their technology teaching support pupils learning. If technology education today have no consensus regarding content and practice (Norström 2014, Skogh 2006) it will result in an insecure teaching. This in turn results in practical activities that do not reflect what the learning outcome would be as the report from School Inspectorate (2014) concludes. We can conclude that the technology subject seems to differ from other subjects as the respondent say they need to teach differently around problemsolving when working with practical activities in technology classroom. This topic we believe other subjects do not include as a feature. Therefore, this particular knowledge practice, as hands-on activities are, need to be further discussed and developed in order to become an important tool for the technology teachers in their teaching. With a clear link between theory and practical activities, an increased learning for the pupils can take place.

The teachers show that they adapt their teaching both to the learners and to the goals they set up. They talk of how colleagues let the pupils work without guidance when they build and construct and the respondents are not in favor to this teaching method. A coherent education seems to be a success factor for the teachers to achieve both goals and have an inclusive education.

The School Inspectorates report indicates that the problem in technology education in Sweden today partly depends of a lack of educated technology teachers. Technology education described by the four experienced teachers, with several years teaching experience, also show that the respondents acknowledge they have problem with certain areas within GPK. The teachers struggle with finding ways for an education that have enough time to process a comprehensive curriculum. This could indicate methods used are not adapted to include all parts of the curriculum but it can also indicate that the curriculum may be too broad and extensive to be completed within the required timeframe.

Conclusion

The respondents' highlight that practical activities are important for the subject as this is appreciated by many students. Also the teachers' finds practical activity rewarding for them in their teaching and important for the pupils for the understanding of the subject content. This is positive. But as hands-on activities are part of the subject it may need a further developed knowledge practice.

The specific GPK that exists in the subject will need to be developed as a knowledgebase to give teachers further tools in handling both theory and practice to evolve pupils learning.

For technology teachers to handle both an extensive core content and tradition in the subject with practical activities, it is important to discuss what GPK teachers need to possess in technology teaching. But it is also useful to apply GPK as an analysis lens to look at teachers knowledges within this area. This can indicate what additional training needs future technology teachers may need knowledge about.

References

Ball, D.L., Thames, M.H., & Phelps, G. (2008). Content knowledge for Teaching: what makes it special? *Journal of Teacher Education*, 59(5), 389-407

Carlgren, I. (2015). *Kunskapskulturer och undervisningspraktiker*. Göteborg: Daidalos.

Ellis, V. (2007). Taking subject knowledge seriously: from professional knowledge recipes to complex conceptualizations of teacher development. *The Curriculum Journal*, 18(4), 447-462

Ethical Review Act (2003). Lag om etikprövning av forskning som avser människor. [The ethical review act]. Swedish law SFS 2003:460. English translation published by the Swedish Ethical Review Board: http://www.epn.se/media/45159/the_etical_review_act.pdf [sic!]

Fisher, C.W., & Berliner, D.C. (1985). *Perspectives on instructional time*. Addison-Wesley Longman Ltd.

Gess-Newsome, J. (1999). Secondary Teachers' knowledge and beliefs about Subject matter and their impact on instructions. In J Gess-Newsome, & N.G. Lederman (Eds.) *Examining pedagogical content knowledge*. Dordrecht: Kluwer

Grossman, P. (1990). *The making of a teacher: Teacher knowledge and teacher education.* New York: Teachers College Press, Colombia University

Grossman, P.L., & Richert, A.E. (1988). Unacknowledged knowledge growth; A re-examination of the efforts of teacher education. *Teaching and Teacher Education* 4(1), 53-62

Hartell, E., Gumaelius, L., & Svärdh, J. (2014). Investigating technology teachers' self-efficacy on assessment. *International Journal of Technology and Design Education*. doi:10.1007/s10798-014-9285-9

Hattie, J. (2003). *Teachers make a difference: what is the research evidence?* Melbourne: Australian Council for Educational Research.

Jones, A., & Moreland, J. (2004). Enhancing practicing primary school teachers' pedagogical content knowledge in technology. *International Journal of Technology and Design Education*, *14*(2), 121-140.

König, J., Blömeke, S., Paine, L., Schmidt, W. H., & Hsieh, F. J. (2011). General pedagogical knowledge of future middle school teachers: On the complex ecology of teacher education in the United States, Germany, and Taiwan. *Journal of Teacher Education*, *62*(2), 188-201.

Leach, J., & Moon, B. (2000). Pedagogy, information and communications technology and teachers' professional knowledge. *The Curriculum Journal*, 11(3), 385-404

Norström, P. (2014). How technology teachers understand technological knowledge. *International Journal of Technology and Design Education*, 24(1), 19-38. doi:10.1007/s10798-013-9243-y.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher,* 15(2), 4–14

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1–22

Skogh, I.-B. (2006). Innovative performance: How can it be assessed? In T. Ginner & J. Hallström (Eds.), *Forskningskonferens i teknikdidaktik: Styrdokument och klassrumsverklighet i skolans teknikundervisning*. Linköping: Linköping University Electronic Press

Skolinspektionen (2014). *Teknik - Gör det osynliga synligt, om kvalitet i grundskolans teknikundervisning*. 2014:04

Skolverket (2011a). *Curriculum for the compulsory school, preschool and the leisure-time centers 2011*. Stockholm. Skolverket [The Swedish National Agency for Education]URL http://www.skolverket.se/publikationer?id=2575

Skolverket (2011). *Diskussionsunderlag till kursplanen i teknik*. (p.5).
  http://www.skolverket.se/publikationer?id=2547

Teknikföretagen & Cetis (2012). *Teknikämnet i träda*. [The Technology Subject Lies Fallow].
  Teknikföretagen, Stockholm

Tekniklyftet. http://www.tekniklyftet.se

A Framework for Enhancing and Assessing Learning of Technology in Early Childhood and Lower Primary School Settings

Wendy Fox-Turnbull
College of Education
University of Canterbury
New Zealand
wendy.fox-turnbull@canterbury.ac.nz

Abstract

This paper describes a proposed study based on teaching and learning in technology education for students aged between four and seven years of age. It aims to explore and develop teachers' understanding of learning in technology through the use of an observation and questioning framework, a tool to formatively assess aspects of technology in the upper early childhood and lower primary school sectors.

Assessment of students' learning and understanding in technology involves intelligent observation of and conversation with children by teachers with the purpose of improving students' technological literacy (Compton & France, 2007). Claxton and Carr (2010) suggest that a number of learning dispositions, orientations or habits are advocated by educators. The dispositions are a way of 'doing' that increases in frequency and complexity, and which can be described with applicable adverbs. These tendencies can be seen as changing over time allowing consideration of what and how teachers can assist their students' progress. Claxton, Chambers, Powell and Lucas (2013) discuss the building of learning power within students through the development of dispositions and attitudes including the building of students' confidence and self-belief in their capabilities, within four domains of learning rather than the building of specific sets of skills.

This study attempts to apply aspects of the above thinking directly to technology education. It is situated within a sociocultural paradigm, employing qualitative research methods to assist teachers through the use of an observation and conversation framework aiming to improve teacher understanding in technology and the giving of formative assessment feedback in technology. An interpretive paradigm will be engaged through the use of observations, video recorded teaching episodes and pre and post semi-structured interviews with teachers.

It is envisaged that this research will take place in three countries, England, Sweden and New Zealand, all with a high reputation in technology education. It is hoped the study will offer an international perspective on ways to broaden and deepen young students' understanding in technological literacy and contribute significantly to the field of formative assessment in technology education.

Introduction:

This paper outlines a proposed study that will investigate a formative assessment tool to assist teachers' understanding of student learning in technology education using a broad framework to assess capabilities and dispositions. Learning behaviours will be explored through the use of an observation and conversation framework to formatively assess aspects of technology education in the upper early childhood (subsequently referred to as early childhood) and lower primary (subsequently referred to as primary) education sectors. In the primary classroom there are times when students might have achieved at one level of the prescribed curriculum but are not ready to move to a higher achievement level. Technology in the early childhood sector tends to be less structured or defined which may present teachers with difficulties with the identification of aspects of technology. Informal assessment occurs across a range of dispositions. Teaching and learning in technology for students aged between four and seven should be designed to build a strong base of understanding and internally driven interest and abilities related to our technological world. It is hoped that the observation and conversation framework introduced in this paper will assist teachers to look for ways to extend students' understanding of the technological world and their place within it.

Technology Education for the Current Century

Learning technology for current and future times presents teachers with a challenge of equipping students with skills and knowledge necessary to thrive in the digital and information ages and beyond. Technology education should recognise and enable students to be mindful custodians of the future as they design and develop technological outcomes which impact the world in unimaginable ways. Wagner (2008) advocates seven survival skills for the twenty-first century:

- Critical thinking and problem solving
- Collaboration across networks and learning by influence
- Agility and adaptability
- Initiative and entrepreneurialism
- Effective oral and written communication
- Accessing and analysing information
- Curiosity and imagination.

Wagner (2008) state that these survival skills need to be taught to our children. Claxton and Carr (2010) suggest thinking about goals of learning or dispositions as verbs rather than nouns so that dispositions are seen not as 'things' to be acquired but rather a 'way of doing' that increases in frequency and complexity and which are described with applicable adverbs. These tendencies can be seen as changing over time allowing us to consider what teachers can do to assist their students' progress. Three adverbial dimensions: robustness, breadth and richness are advocated by Claxton and Carr and can be used to measure progress. The first, 'robustness' is defined as a tendency to respond to learning in a positive way when conditions for learning are not as supportive as they once were. The second dimension, 'breadth' is concerned with the understanding that what is learned in one domain can be transferred to other settings. This is also known as knowledge transfer. "Richness' is the third dimension and involves the development of flexibility and sophistication of thinking.

Claxton, Chambers, Powell and Lucas (2013) discuss the building of learning power within students through the development of dispositions and attitudes including the building of students' confidence and self-belief in their capabilities, within four domains of learning rather than the building of specific sets of skills. Within Claxton et al.'s four domains: resilience, resourcefulness, reflectiveness and reciprocity sit a number capabilities, some of which are particularly relevant to technology education such as: noticing, perseverance, managing distractions and absorption in the resilience domain; making links, questioning and imaging in Resourcefulness; planning and distilling in Reflectiveness and collaboration, empathy, inter-dependence in Reciprocity. Claxton

and colleagues (2013) state that increasing students' curiosity, sense of adventure, perseverance, and independence along with teaching students how to be better learners increases also their capabilities.

Assessment of students' learning and development in technology involves intelligent observation of and conversation with students by teachers with the purpose of improving students' technological literacy (Compton & France, 2007). This research suggests that understanding the relevant dispositions in the context of technology could be useful in assisting teachers' ability to understand and develop ideas of student progression. Progress in technology is not linear, but rather a holistic process which can be difficult to assess (Kimbell, 1997). Achievement in technology includes a students' conceptual understanding of subject matter and their ability to transfer concepts to future learning and both new and unfamiliar situations (Pellergrino, 2002). National or state curricula such as New Zealand's national curriculum technology achievement objectives (Ministry of Education, 2007) and the United Kingdom's Key Stages (Department of Education, 2013a) in design and technology (d&t) go some way to identifying progression in technology. Compton and Harwood, (2005) Jones (2009) and Pellegrino (2002) suggest more research is needed around the notion and specifics of progression in technology. The tool developed for this research hopes to offer some assistance for teachers in understanding some underlying key concepts in technology through the use of key aspects for both primary and early childhood by looking at them through a modified and blended version of Claxton and Carr's (2010) perspectives and Claxton et al.'s (2013) domains and capabilities.

International Perspectives of Technology
Primary

In the New Zealand curriculum (NZC) (Ministry of Education, 2007) technology is organised into three strands: Technological Practice, Technological Knowledge and the Nature of Technology. Students work on developing technological outcomes to meet identified needs and opportunities. They are required to develop an understanding of technology and the impacts and influences it has on people and the environment. Finally they are required to have knowledge of key concepts unique to technology such as understanding the purpose and type of modelling and understanding how properties of materials can impact on the functional nature of outcomes. Students work across a range of technological areas including: biotechnology, control, food, information and communication and structural and within a variety of authentic contexts.

In England d&t programme of study in primary begin with Key Stage 1 (Years 1 and 2). It aims to ensure that all students: develop the creative, technical and practical expertise needed to perform everyday tasks confidently and to participate successfully in an increasingly technological world, build and apply a repertoire of knowledge, understanding and skills in order to design and make high-quality prototypes and products for a wide range of users, critique, evaluate and test their ideas and products and the work of others and understand and apply the principles of nutrition and learn how to cook (Department of Education, 2013b, p. 181). Students also work within a range of relevant contexts when designing and making, and should be taught to: design, make and evaluate technological outcomes.

In Swedish elementary (primary) schools technology is aimed at helping students develop expertise and awareness of the technical world. Students are expected to develop skills to enable them to analyse technological solutions, identify technological problems and needs, use concepts and expressions of technology, assess the consequences of technology and identify the driving forces of technology. In primary schools students are also required to take arts and crafts subjects which included working in wood, metal and textiles (Fahrman, Gumaelius, & Norström, 2015).

Although clearly different, the above primary technology curricula do have commonalities. Listed below are the aspects that I believe to be the most significant commonalities.

By studying technology students should gain:
1. an understanding of their technological world
2. the ability to evaluate (analyse and critique) current technologies
3. the ability to identify potential technological problems, needs or opportunities
4. the ability to design and make technological outcomes to meet identified needs using a range of materials
5. understanding of key concepts and processes unique to technology and deploy these in their practice where applicable.

Early Childhood

The New Zealand early childhood curriculum for children from 0-6 years of age is called Te Whāriki (Ministry of Education, 1996). It consists of five strands: Well-being, Belonging, Contribution, Communication and Exploration within which sit a number of goals. Its underlying philosophy emphasises the critical role of socially and culturally mediated learning and of reciprocal and responsive relationships for children with people, places, and things. It states that children learn through collaboration with adults and peers, through guided participation and observation of others, as well as through individual exploration and reflection (Ministry of Education, 1996).

The early years foundation stage (EYFS) in England sets standards for children from birth to five years old. Six overarching principles shape practice in early childhood settings. These are that every child is unique; that children are constantly learning and can be resilient, capable, confident and self-assured. Children learn to be strong and independent through positive relationships. They learn and develop well in enabling environments, in which their experiences respond to their individual needs. There is a strong partnership between practitioners, parents and/or carers and children so that they are able to develop and learn in different ways and at different rates (Department of Education, 2014). The areas of learning are:
• communication and language
• physical development
• personal, social and emotional development
• literacy
• mathematics
• understanding the world
• expressive arts and design.

In Sweden early childhood education is based on a comprehensive holistic view of the children. Sweden recognises children to be individuals with their own rights who are active and competent. They believe that children influence, and are influenced by their surroundings therefore learning and development processes happen any time and does not always correspond to what adults had in mind. Learning and development are best promoted through play when children have fun and may concentrate on the things they are interested in (Engdahl, 2004). Swedish early childhood education is underpinned by the following philosophies. Children:
• need a sense of independence as well as adult supervision
• need a stimulating and challenging learning environment
• need space and fresh air for their physical and mental development
• require well-planned learning activities that must be in place to help children develop sense of achievement and social skills.
• need plenty of learning opportunities
• undertake learning opportunities to develop positive attitudes towards learning and learning process. It is equally important for them to develop constructive attitudes towards their peers and adults.
• need to get the balance right in terms of indoor and outdoor activity
• need time to achieve planned goals and objectives

- must be given opportunity to explore a variety of materials, become familiar with different colour, shape, texture and sound.
- should be given plenty of opportunities to and encouraged to express their ideas, communicate their feelings and more importantly use their imagination
- should be given plenty of opportunities to draw pictures; these become more detailed compared as their ability to concentrate increases.
- need their pictures and other kinds of work praised.
- should be given opportunity to value their own and other children's work (Özar, 2012).

In the early childhood sector the commonalities relate to students' place in the world and their ability to contribute to it. All three countries promote a holistic approach to early childhood education with technology implied or specifically mentioned. In New Zealand Te Whāriki (Ministry of Education, 1996) has technology foundational knowledge and skills embedded in it pages. These include the capability to solve practical problems from the 'Well-Being' strand; using materials for different purposes and recognition that different technologies may be used in a variety of settings and places in the 'Belonging' strand. Experiencing collaborative and cooperative problem solving and understand how technologies assist people in the 'Contribution' strand also make reference to technology. The use of communication technologies is stated the 'Communication' strand, and exploring variety of technologies for different purposes is stated in the 'Exploration strand'. The 'Exploration' stand also contains more specific activities and exploration directly applicable to technology (Mawson, 2003). Several learning examples are directly related to the use and construction of technology, these include: offering degrees of challenge in construction activities, using technology to explore movement in objects such as wheels and pulleys and creating three dimension constructions. Others relate to technological process such as using trial and error to find solutions, giving reasons for choices, developing spatial understanding by fitting things together and taking things apart, and exploring the nature and properties of materials and substances. In England the areas of learning most relevant to technology include: communication and language, understanding the world, expressive arts and design as wells as mathematics and literacy. The principles of resilience, capability and confidence also have strong links to thriving in a technological world. In Sweden technology is clearly evident in the underlying beliefs that children are active and competent, interested, influence, and are influenced by their surroundings.

To summarise key aspects of technology of all three nations in early childhood settings I suggest the following:
Children in early childhood education learn technology through:
1. exploration of the made-world
2. communicating ideas about the made-world
3. independent engagement in and with technology
4. contributing to the made-world through making and construction in a range of areas
5. the development of resilience, resourcefulness, reflectiveness, reciprocity, a sense of self and of achievement when undertaking the above.

Research Questions
 The research question for this study is "How will the developed observation and conversation framework based on behaviours of learning enhance teachers' understandings of student achievement in technology?"

Sub questions:
1) What are teacher attitudes and opinions about using the framework to formatively assess and enhance student learning in technology?

2) How effective is the framework in assisting teachers in the identification of students' learning in technology?
3) What aspects of the framework are most successful at enhancing the quality of teacher/students conversation?

Methodology and Methods

This research will be situated within a sociocultural paradigm and will employ a interpretative qualitative research method (Ritchie, Lewis, McNaughton Nicholls, & Ormston, 2014) through the applications of the developed observation and conversation framework by teachers to assist them in broadening their understanding of students' learning and assisting in the giving of feedback to students as a part of the formative assessment process in technology (Neuman, 2011). The main data will come from pre and post semi-structured interviews with the teachers. This research will take place in three countries, England, Sweden and New Zealand, all with a high reputation in technology education. The research plans to present teachers with a framework to assist their observations and structuring of conversations with their students. Data will be triangulated through researcher observations and video recording of teachers' conversations with students. Ethical clearance from the University of Canterbury (UC) ethics committee was obtained. Consent will be obtained from all teachers involved in the study and their schools' principals. Data analysis will occur through repeated coding and recoding (Neuman, 2011) to enable a rich description of the teachers' experiences using the framework. After the analysis of early data it is envisaged that the framework may need to be altered before further data gathering occurs.

Developing the Framework

The dimensions and domains discussed in previous sections will be applied to the assessment of technology education in both primary and early childhood settings. Formative and summative assessment in technology in primary settings occurs through a range of strategies such as observations, work samples and student portfolios of technology practice (Moreland & Jones, 2000). In New Zealand for example teachers use information gained through the above methods to assess students' learning against a set of achievement objectives identified in technology (Ministry of Education, 2007), which are extrapolated into indicators of progression at each curriculum level (Ministry of Education, 2009a) to assist teachers in their assessment judgements and feedback.

In early childhood settings assessment occurs minute by minute as teachers and peers listen, watch, and interact with children or groups of children. Continuous observations provide the basis of information for more in-depth assessment and evaluation that is integral to making decisions on how best to meet students' needs. Assessment of the early childhood environment should always focus on individual children over a period of time and avoid making comparisons between children (Ministry of Education, 1996). In New Zealand Narrative Assessment (Ministry of Education, 2016) is commonly used in early childhood settings. Undertaking narrative assessment provides the teachers with an account of what the child said and did as well as provide a description of the child and setting. The learning stories, written as a part of the Narrative Assessment process, highlight the learning in key areas such as competencies and learning areas. Narrative Assessment also involves an analysis of what happened by making explicit links to curriculum or other official documents. Narrative Assessment stories also include information and ideas about where to next for the learner and a statement about the pedagogy evident in the episode recorded and the improvements that might be made (Ministry of Education, 2009b). When using this framework teachers will be encouraged to use ongoing formative assessment and Narrative Assessment processes to reflect on action and learning occurred.

Conversation Framework

184

The proposed framework identifies five behaviours modified from Claxton and Carr's (2010) dimensions and Claxton et al.'s (2013) domains that may contribute to success in technology. The term 'behaviours' is used in the broadest sense to incorporate cognitive, social and physical behaviours. Located within each behaviour are a number of capabilities to assist teachers in the recognition of the behaviours. The behaviours and capabilities are outlined in Table 1 below.

Table 1: Potential Behaviours Underpinning Success in Technology

Behaviours: Demonstration of:	Resilience	Transference	Flexibility & Sophistication	Reflection	Socialisation
Capabilities	Perseverance Managing Distractions Absorption	Making Links Imaging Noticing Questioning	Planning Distilling Reasoning Imagining Capitalising Evaluating	Questioning Distilling Revising Meta Learning Evaluating	Empathy & Listening Collaboration Interdependence Imitating

The first of the behaviours is the demonstration of Resilience modified from Claxton and Carr's (2010) Robustness dimension for clarity and to align with one of the four domains used by Claxton et al.(2013). Resilience includes capabilities of perseverance especially after initial failure, managing distractions from peers, other activities and people around them, and absorption in any given task. Absorption can be likened to Csikszentmihalyi's (1990) state of 'Flow' and is described as a state of deep absorption in an activity that is intrinsically enjoyable, as when artists and athletes are focused on their play or performance (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). I believe this is the same or similar with children and students. When totally absorbed in tasks they often do not hear or respond to what is going on around them.

The second behaviour, Transference includes making links to technologies experienced or seen, and experiences undertaken previously such as using existing cultural knowledge and experiences or Funds of Knowledge (González, Moll, & Amanti, 2005). It also includes questioning the relevance of previous experiences and imaging how existing knowledge and skills might be transferred to new situations to assist and or improve performance.

Flexibility and Sophistication describe what Claxton and Carr (2010) called Richness. The new term is used to ensure the meaning is more explicit and assists ease of use. In this behaviour category students will demonstrate increased depth to their understanding as well as an openness to new and potentially strange ideas. This will involve use of reasoning to evaluating and distilling information received in order to understand what is learned from an experience. It also includes the questioning of relevance and asking questions of others to learn more by getting below the surface of ideas and artefacts. Planning ideas and actions and capitalising or making the best use of resources also characterise this behaviour. Recent research suggests there is an intuitive connection between creativity and cognition (Lewis, 2008; Runco, 2014) and Spendlove (2015) identifies strong societal benefits of being creative within technology education. Increased sophistication of ideas therefore may lead to improved creativity.

Reflection, the fourth behaviour identified, comes directly from Claxton et al.'s (2013) domain of the same name and describes the strategic and self-managing aspect of learning. Reflection includes the planning and anticipating of needs and potential issues and distilling information for potential of future use. It includes the revision of prior learning and its evaluation as a part of the distilling process to identify relevant learning that can therefore be transferred to a new context. Finally

this will involve self-generated questioning and self- monitoring of progress through being cognisant of what, how and why learning is taking place.

The fifth and final behaviour is Socialisation. The inherently social nature of technology and technology education and the huge physical, social and environmental impacts of technology make inclusion of this behaviour vital. Claxton et al.'s (2013) Reciprocity domain suggests this. Whether engaging in the use or the development of technology students will be interacting in a social manner. They may be collaborating with others to develop single or parallel technologies, they will experience interdependence, or the balancing of self-reliance and socialisation, as the need for resources and skills arise. Even when using a piece of technology in a solitary manner students are still engaging with people. Their evaluation of the technology and decision making about whether to come back for further engagement or not will impact other people in the long-term if not sooner. For example teachers will not purchase a technological device, toy or piece of equipment that their students choose not to engage with. Understanding how others' think by demonstrating empathy and listening or by imitating behaviour also impacts on engagement with technologies and technology practice.

The framework will comprise of the above behaviours looked at against the five primary and first four early childhood key aspects identified earlier in this paper. Key points for observation and specific and general questions will be suggested in the framework to assist teachers when observing and talking to their students while engaging with and in technology. Table 2 outlines the unpopulated framework to be used in early childhood settings (4-5 years) and Table 3 outlines the unpopulated framework to be used with primary children (5-7 years).

Table 2: The Unpopulated Childhood Observation and Questioning Framework

Behaviours Aspects	*Resilience*	*Transference*	*Flexibility & Sophistication*	*Reflection*	*Socialisation*
Exploration of the made-world	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:
Communicating ideas about the made-world	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:
Independent engagement in and with technology	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:
Contributing to the made-world through making and construction in a range of areas	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:

Table 3: The Unpopulated Primary Observation and Questioning Framework

Behaviours Aspects	Resilience	Transference	Flexibility & Sophistication	Reflection	Socialisation
Understanding of the technological world	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:
Evaluate current technologies	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:
Identify technological problems or needs	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:
Design & make technological outcomes to meet needs	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:
Understand key concepts of technology & deploy in their practice	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:	Look for: Ask:

At the time of writing this paper the points of observation and key questions were yet to be developed. The framework will be piloted in New Zealand in the coming months, the data analysed and framework and its components modified according to the feedback from the first two teachers. These changes and the final framework will be shared in my conference presentation.

Conclusion

This paper outlined a proposed study aimed at enhancing teachers understanding of learning in technology thus enabling them to use informed formative assessment judgements to enhance students' learning in technology. The study will be undertaken in the second half of 2016 in the international arena. The study brings together key behaviours essential for learning with key aspects of technology from three countries to create a tool that aims to assist teachers' understanding of students' learning through the use of formative and narrative assessment processes in technology. It is hoped that this study will offer an international perspective on ways to broaden and deepen young students' understanding in technological literacy and will contribute significantly to the field of formative assessment in technology.

References

Claxton, G., Chambers, M., Powell, G., & Lucas, B. (2013). *The learning powered school: Pioneering 21st century education*. Bristol TLO Limited.

Claxton.G., & Carr, M. (2010). A framework for teaching learning:the dynamics of disposition. *Early Years: An International Journal, 24*(1), 87-97.

Compton, V., & France, B. (2007). Towards a new technological literacy: curriculum development with a difference. *Curriculum Matters 3*, 158-175.

Compton, V., & Harwood, C. (2005). Progression in technology education in New Zealand: components of practice as a way forward. *International Journal of Technology and Design Education, 15*, 253-287.

Csikszentmihalyi, M. (1990). Flow: The psychology of optimal experience. New York: Harper-Perennial.

Department of Education. (2013a). *The national curriculum in England: framework document*. London: Department of Education Retrieved from www.gov.uk/dfe/nationalcurriculum.

Department of Education. (2013b). *Statutory guidance: national curriculum in England: design and technology programmes of study.* Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/425601/PRIMARY_national_curriculum.pdf

Department of Education. (2014). *Statutory framework for the early years foundation stage: setting the standards for learning, development and care for children from birth to five.* Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/335504/EYFS_framework_from_1_September_2014__with_clarification_note.pdf

Engdahl, I. (2004). Implementing a national curriculum in Swedish preschools *International Journal of Early Childhood Education 10*(2), 53-78.

Fahrman, B., Gumaelius, L. B., & Norström, P. G. (2015). *Technology education in primary school in Sweden: a study of teachers views on teaching strategies and subject content* Paper presented at the 122nd ASEE Annual Conference & Exposition, Seattle USA.

González, N., Moll, L. C., & Amanti, C. (Eds.). (2005). *Funds of knowledge* (1st ed. Vol. 2009 Reprint). New York: Routledge.

Jones, A. (2009). Towards an articluation of students making progress in learning technological concepts and processes. In A. Jones & M. de Vries (Eds.), *International handbook of research and development in technology education*. Rotterdam: Sense Publishers.

Kimbell, R. (1997). *Assessing technology international trends in curriculum and assessment*. Buckingham: Open University Press.

Lewis, T. (2008). Creativity in technology education: providing children with glimpses of their inventive potential. *International Journal of Technology and Design Education*, 255-268. Retrieved from doi:DOI 10.1007/s10798-008-9051-y

Mawson, B. (2003). Smoothing the path: technology education and school transition. *Research in Science Education, 33*, 503-514.

Ministry of Education. (1996). *Te Whāriki early childhood curriculum*. Wellington, New Zealand: Learning Media.

Ministry of Education. (2007). *The New Zealand curriculum*. Wellington: Learning Media.

Ministry of Education. (2009a). *Indicators of progression.* Retrieved from http://techlink.org.nz/curriculum-support/indicators/index.htm

Ministry of Education. (2009b). *Narrative Assessment: a guide for teachers*. Wellington: Learning Media Retrieved from http://assessment.tki.org.nz/Assessment-tools-resources/Tools-for-Learners-with-Diverse-Learning-Needs/Narrative-assessment.

Ministry of Education. (2016). *Narrative assessment.* Retrieved from http://assessment.tki.org.nz/Assessment-tools-resources/Tools-for-Learners-with-Diverse-Learning-Needs/Narrative-assessment

Moreland, J., & Jones, A. (2000). Emerging assessment practices in an emergent curriculum:implications for technology. *International Journal of Technology and Design Education, 10*(3), 283-305.

Neuman, W. L. (2011). *Social research methods: qualitiative and quantitative approaches* Boston USA: Pearson.

Özar, M. (2012). Curriculum of preschool education: Swedish approach. *International Journal of Business and Social Science 3*(22), 248-257

Pellergrino, J. W. (2002). *How people learn: contributions to framing a research agenda for technology education* (Vol. 2). Gold Coast, Australia: Centre for Technolgy Education Research

Ritchie, J., Lewis, J., McNaughton Nicholls, C., & Ormston, R. (Eds.). (2014). *Qualitative research practice: a guide for social science students and researchers*. London: Sage Publications Ltd.

Runco, M. A. (2014). *Creativity: theories and themes :research, development, and practice* (2 ed.). London Academic Press Elsevier.

Shernoff, D. J., Csikszentmihalyi, M., Schneider, B., & Shernoff, E. S. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly, 18*(2), 158-176.

Spendlove, D. (2015). Developing a deeper understanding of design. In P. J. Williams, Jones, A., Bunting, C. (Ed.), *The future of technology education: contemporary issues in technology education series*. Singapore: Springer.

Wagner, T. (2008). *The global achievement gap: why even our best schools don't teach the new survival skills our children need- and what we can do about it.* New York: Basic Books.

The Swiss compromise: technology education spread over five different subjects

Karin Güdel
University of Applied Sciences, Department of Teacher Education
Basel, Switzerland
karin.guedel@fhnw.ch

Abstract

Until now, technology education has been assigned a rather marginal position in Swiss schools. With the new national curriculum "Lehrplan 21" technological literacy seems to receive more attention. References to technology education are not only made in the subject "Technical and Textile Design", but also in "Nature and Technology", "ICT and Media" and "Economy, Labour and Housekeeping". With the aim of pooling resources and strengthening technology education in Switzerland, we determined the contributions of the different subjects by analyzing international literature and national curricula/standards for technology education, focusing on subject areas, basic concepts and competency areas. Our findings show a quite disillusioning result: the only subject that effectively contributes to technology education is "Technical and Textile Design", but merely with a strong focus on design and just in the following subject areas: games and leisure, textiles and fashion, construction and living, mechanics and transport, energy and electricity. In the subject "Nature and Technology", however, technological skills are solely imparted via the application of science, i.e. by presenting ways of understanding concepts of science or functions of commodity items. Basic concepts of technology education like product lifecycles, systems, resources and values, and the subject areas manufacturing, biomedical, water and safety technologies are not explicitly mentioned in the curriculum. Being aware of this, we are currently trying to integrate some of these missing basic concepts and subject areas into teacher education at lower secondary school level and generate synergies in a new interdisciplinary master's course. At the conference the curriculum analysis and a first conceptual draft of an interdisciplinary technology course for lower secondary level school teachers is presented.

Keywords: Technology, education, curriculum, basic concepts, subject areas, technological literacy

1   Current situation in Switzerland

A comparison between former and new Swiss curricula and other national curricula/standards that contain the subject "Technology" (e.g. US, New Zealand, Germany) reveals considerable differences: in Swiss schools, the systematic development of technological competencies is not explicitly prescribed. Although pupils get the opportunity to learn about technology in science education (presented in the form of applied physics/chemistry/biology) and handicraft (technical and textile design), the curricula neither encompass nor integrate important elements of a holistic technology education, e.g. social, historical and ethical aspects.

Undoubtedly, there are and have always been teachers who show a special interest in technology and familiarize their pupils with technology, but most children and adolescents get in touch with technology only in informal settings. For the average Swiss girl aged between 13 and 14 this means that she might not have the opportunity to gain experience with technology, neither at school nor at home. This is quite problematic, because different studies indicate that choosing a

career in one of the manifold vocational fields of technology significantly correlates with previous contacts with technology (Boerlin et al., 2014).

The new Swiss curriculum "Lehrplan 21" (D-EDK, 2016), which is to be introduced in all 21 German-speaking cantons in the next years, mentions technology in connection with the subjects "Technical and Textile Design" (formerly "Handicraft"), "Nature and Technology" (formerly "Biology", "Chemistry" and "Physics"), "Economy, Labour and Housekeeping" (formerly "Health and Domestic Economy") and "ICT and Media" (did not exist before) (Fig. 1; in detail: Section 2).
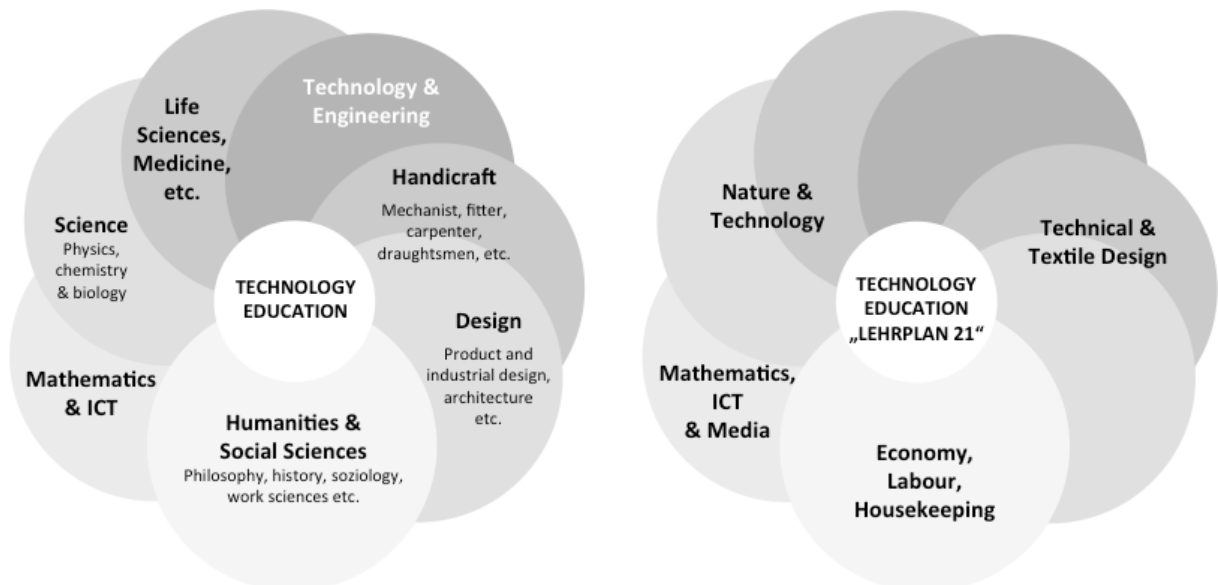
Figure 1: Illustration of different domains of technology education in tertiary education and vocational training (left) and corresponding subjects relating to technology education at school according to "Lehrplan 21" (right).

A comparison of studies in technology in tertiary education and vocational fields with subjects of technology education at school (Fig. 1) shows that the domain of technology and engineering is insufficiently covered by the subjects that are stipulated in "Lehrplan 21". One goal of the politically motivated STEM-initiatives (German MINT-initiatives), which are often justified with economic arguments (lack of skilled workers), is to close this gap resp. strengthen technology and engineering. Yet the fact is, that the Swiss curriculum designers "enrich" education in natural sciences with subject matter from technology ("Nature & Technology"), whereas "soft" subjects like arts and handicraft are cut down (fewer prescribed lessons per week, less significance in teacher education etc.). Thus the positively intended STEM-initiatives partly miss their educational objectives. Firstly there are not enough competent STEM-teachers. Secondly, the structural conditions (classrooms, time allocation, infrastructure etc.) are not given, and, finally, the aim of such "programs" or "initiatives" is hardly ever clearly defined.

In view of this situation and the fact that young people are permanently surrounded and increasingly influenced by technology, Swiss schools and teacher education are undeniably required to strengthen technology and engineering by integrating them into technology-related subjects like science or technical design. Before expounding on this point (Section 3), the contributions of different existing subjects to technology education in Swiss schools shall first by systematically analysed.

2 Curriculum analysis

With the goal of getting a broader picture of the international 21st-century trends and skills in technology education, and comparing them with the "Lehrplan 21", we analyzed international literature and national curricula/standards for technology education. We mainly focused on subject areas, basic concepts and competency areas, and compared the terms and the general structure, as an in-depth analysis of curriculum elements with examples of standards was not possible. Because of linguistic boundaries and a limited body of thematic literature, we restricted the review to the Delphi study by Rossouw et al. (2011) and to curricula/standards of English- and German-speaking countries that had been revised in the past ten years: the American Standards of Technological Literacy (ITEA, 2007), the national Curricula of New Zealand (2014) and England (2013), and the German educational standards for technology education (VDI, 2007). Parts of this section will be published by Guedel & Heitzmann (2016).

2.1 Subject areas of technology education

Technology education can, or rather, should be realized in different subject areas. The left-hand column of Table 1 provides an overview and a comparison of the broad and steadily expanding range of important subject areas of technological literacy, while the right-hand column lists those subject areas of the STEM subjects in the Swiss "Lehrplan 21" which bear a relation to the subject areas of technology education. The overview shows that "Technical & Textile Design" covers the subject areas "Construction & living", "Mechanics & transportation" and "Energy & electricity", whereas "Nature & Technology" gives theoretical and scientific background to these subject areas; "Economy, Labour, Housekeeping" furthermore encompasses the subject areas "Manufacturing & labour", "Nutrition & health" and "Consumption"; and "ICT & media" integrates "Information & communication".

Table 1: Main subject areas of technology education (left) and connection with technology education according to "Lehrplan 21" (right) (the darker the shading, the closer to technological skills)

Subject areas of technology education (international comparison)			Subject areas with connection to technology education according to "Lehrplan 21" (STEM subjects)		
Contexts of Delphi Study (Rossouw et al., 2010)	Areas of the Designed World (ITEA, 2007)	Fields of activity (Schmayl, 2004; VDI, 2007)	Nature & Technology (NT); Economy, Labour, Housekeeping (WAH)	Technical & Textile Design	Mathematics, ICT and Media
Production and manufacturing	Manufacturing technologies	Work & production	Manufacturing & labour (WAH)	Textiles & fashion	Number & variable
Shelter	Construction technologies	Construction & Living	Mechanical and electrical phenomena (NT)	Construction & living	Shape and space
Mobility	Transportation technologies	Transportation & Mobility	Energy transformation (NT)	Mechanics & transportation	Quantities, functions, data, probability
Energy	Energy & power technologies			Energy & electricity	
Food, water	Agricultural & related biotechnologies	Supply & disposal	Nutrition & health (WAH) Consumption (WAH)		
Biomedical technology	Medical technologies				
		Housekeeping & leisure		Games and leisure	
Safety		Protection & safety			
Communication	Information & communication	Information & communication			Information, communication

2.2 Basic concepts of technological literacy

Analogous to other subjects, it is quite difficult for technology education to deal with the complexity and the variety of the virtually innumerable and highly specified domains of its reference disciplines (Fig. 1). Therefore it is important to define and agree on relevant basic concepts. Different countries and research groups have taken different approaches to specifying such basic concepts of technology education (Rossouw et al., 2011; ITEA, 2007; VDI, 2007). The following ones are recurrently and unanimously considered important:

- systems: artefacts, structures and functions;
- resources: materials, energy and information;
- design(ing): invention, innovation, sustainability, manufacturing;
- values and sense-making: social interaction, risks and impacts of technology.

Several basic concepts of technology education like e.g. "structures and functions" or "resources" are tightly associated with science-based concepts. "Design(ing)" is being closely related to "Technical and Textile Design", whereas others like "values and sense-making", even if they are attributed to the subject area "Economy, Labour, Housekeeping" are important for all subjects as soon as human and social perspectives are taken in account.

2.3 Competency areas and standards for technological literacy

Alongside the international trend towards output-orientation in education systems and an extensive implementation of educational monitoring, some countries have developed competency-based

curricula and standards for technology education in the past decade (Table 2). A comparison with the Swiss standards for technical design and science reveals some interesting points:

- The American standards for technological literacy (ITEA, 2007) follow their own structure which cannot be directly related to the other standards or curricula (omission of manifest rows in Table 2).
- The technology standards of other countries (here for example New Zealand, England and Germany) are structured in a similar way: three main competency areas can be distinguished, two of them being analogous to science competency areas such as "knowledge/understanding" (specified for basic concepts) and "communication and evaluation" (they are represented by three continuous rows in Table 2); while the third one manifests a singularity of technology called "technological practice" or "products and processes", which is divided into "design(ing)" and "make"/"utilizing" as typical technical and technological methods for acquiring and generating knowledge and developing products.
- The Swiss Curriculum follows the traditional standards for science and focuses explicitly the competency of technological practise in the subject "Technical and Textile Design".

Table 2: Competency areas and standards for technology education, technical and textile design and science: comparison between international standards (white) and the Swiss curriculum "Lehrplan 21" (dark)

Competency and standard areas of technology education (international comparison)				Competency and standards areas of two Swiss subjects	
USA: standards (ITEA, 2007)	**New Zealand 2014** (National Curriculum)	**England 2013** (National Curriculum)	**Germany: competence areas** (VDI, 2007)	***Technical and Textile Design*** *("Lehrplan 21"; D-EDK 2014)*	***Science standards*** *(Konsortium Harmos NaWi+, 2010)*
Nature of technology basic concepts (Sect. 2.2) **Technology and Society** **Design** **Abilities for a technological world** **The designed world**	**Technological knowledge**	**Understand**	**Understand technology** basic concepts (Sect. 2.2)	**Contexts and Orientation** Understanding of design & technology, culture, history	**Expert knowledge** basic knowledge & concepts (Sect. 2.2)
	Technological practice	**Design**	**Designing and constructing technology**	**Processes and Products** Design processes, function & construction, design elements	**Methods for gaining knowledge** scientific principles of thinking and operation, design experiments etc.
		Make	**Utilizing technology**	Techniques, materials, tools and machines	
	Nature of technology	**Evaluate**	**Communicating & evaluating technology**	Perception & Reflection Communication & documentation	**Evaluation and communication**

2.4 Principal findings of the curriculum analyses

As the analyses of subject areas, basic concepts and competency areas show, the specification of technological literacy in the Swiss curriculum "Lehrplan 21" differs quite remarkably from other conceptions. The subject "Technical & Textile Design" plays a key role in Switzerland, although the standing of technical design in compulsory education is rather low. This becomes apparent in the small number of lessons (two lessons per week at most, sometimes only as an elective subject) as well as in the fact that the subject does not exist at high-school level ("Gymnasium"). Thus,

"Lehrplan 21" has not sufficiently clarified the positioning of technology and engineering within general education. Besides the new focus on "Nature of Science and Technology", it mentions hardly any technological competencies that relate to the subject "Nature and Technology". Technology merely ranks as an application of the natural sciences, which is not wrong, but certainly not sufficient. Given both the absence of the distinct subject "Technology" in "Lehrplan 21" and the present integration of technology education into at least four other subjects, the need for interdisciplinary teaching becomes evident.

3 The Swiss compromise: interdisciplinarity

As one result of the curriculum analysis we organised a symposium on "The contributions of different school subjects to technology education", held at the research conference of the School of Education in Basel in November 2015. We invited chairs of teams who deal with different technology-related subjects, and asked them to present their understanding of technology education and their contribution to teaching this multifaceted domain. While discussing the wide range of involvements, we realized how much expertise the School of Education actually unites. As, however, hardly any efforts to pool this expertise had been made in the past and teacher's education could not benefit from this synergy potential.

3.1 Joining forces: An interdisciplinary approach to technology education

Taking advantage of the current curriculum reform at the School of Education, we decided to develop an interdisciplinary master's course in technology education to be offered in fall 2017. Taking the main goals, subject areas, basic concepts, and competency areas of technology education and "Lehrplan 21" (Section 2) into consideration, an outline of this course was sketched. The major challenges and potentials of the interdisciplinary approach are the following:

- Master students from five different subjects who study to become lower secondary school teachers will attend the course.
- A group of teacher educators from five or more different subjects will teach the course and offer multidisciplinary projects/assignments (Table 3), where students can gain technological experiences themselves and have to deal with the transfer and adjustments for their pupils of lower secondary school level.
- Since it is a master's course in subject pedagogy, a strong focus not only on general content knowledge, but also on pedagogical content knowledge is necessary.

So as to be able to cope with these challenges and to realize the potentials, we draw on existing structures and materials from other countries, and integrate the expertise of our colleagues as far as possible.

3.2 Concept of an interdisciplinary master's course

By designing and offering the master's course „Interdisciplinary Technology Education", we aim to

1. introduce the multifaceted domain of technology and engineering in a way that is not specific to a particular subject and broaden their understanding of the "Designed World" (Table 3). For doing so, the basic concepts and competency areas of technology education which are missing in "Lehrplan 21" are introduced;

2. provide students with the opportunity to gain subject-specific technological experience in at least two different subject areas.

One idea is to structure the course according to the American Standards for Technological Literacy (ITEA, 2007). The advantage of this approach consists in not having to divide technology into the competency areas "understanding", "making" and "evaluating". This prevents us from identifying them with traditional subjects or stereotypes such as:

- understanding = science;
- making = technical design;
- evaluating, questioning, communicating = (if at all) technical design; economy, labour and housekeeping; history; philosophy.

By taking an integral approach, these common stereotypes are not perpetuated. Technical design is not limited to "making"; other competency areas like "understanding" and "evaluating", or "contexts and orientation", "perception & reflection" and "communication & documentation" are equally important (Table 2).

A rough conceptual draft of the course comprises the components presented in Table 3. It is designed for a total workload of 60 hours (2 ECTS), including fourteen teaching sessions of 90 min. The following main steps and rows in Table 3 can be distinguished:

1. At the beginning of the course different projects, learning environments and/or assignments pertaining to the subjects are presented.
2. About three sessions deal with technology and design in general. They make use of examples taken from different subjects.
3. The main part of the course (ca. 8 sessions) consists of group work in two different projects with two different approaches to technology and interdisciplinarity (cf. 1).
4. As to make the picture complete, the students are provided with a body of teaching materials, web-links, and information which is not structured according to distinct subjects, but with respect to the "Designed World".
5. At the end of the course, the students are required to present their products, project outcomes and pedagogical reflections.

Table 3: Course structure following the American Standards for Technological Literacy (ITEA, 2007) and the subjects involved

Course elements	*Course contents and selected competencies to be acquired according to ITEA (2007)*	*Non-specific*	*Technical & Textile Design*	*Nature & Technology*	*Economy, Labour, Housekeeping*	*Media & Computer Science*	*Music*
1 (1 session)	Teacher educators introduce and present different projects from different subjects with different approaches to interdisciplinary teaching		X		X	X	X
2 (3 sessions)	Students develop an understanding of the **Nature of Technology**. This includes acquiring knowledge of: • The characteristics and scope of technology • The basic concepts of technology	X		X Comparison with nature of science			
	Students develop an understanding of **Technology and Society**. This includes learning about: • The cultural, social, economic, and political effects of technology • The effects of technology on the environment • The influence of technology on history	X	X (pedagogical example: craft history)	X (pedagogical example: history of science)	X (pedagogical example: food and nutrition)	X (pedagogical example: computer science)	X (pedagogical example: music industry)
	Students develop an understanding of **Design**. This includes knowing about: • The attributes of design • Engineering design	X	X (design process)	X (comprehension process)			
3 (two projects/assignme	Students develop **Abilities for a Technological World**.		X Three different design		X Assignment	X Programming a	X Assignment

			assignments joining design process and scientific knowledge process; 3 different contexts	on food production and manufactu ring	computer game (subject area: "Information & Communicati on")	on instrume nts or music industry (subject area: "Leisure")
nts; 4 sessions)	This includes becoming able to: • Apply the design progress • Use and maintain technological products and systems • Assess the impact of products and systems					
4 (1 session)	Students develop an understanding of the **Designed World**. This includes selecting and using: • Work & manufacturing • Household & leisure • Construction & living • Transportation & mobility • Supply & disposal (water, food, etc.) • Energy technologies • Agriculture, biotechnologies, medical technologies • Safety • Information & communication	X Familiarization with all domains of technology; compiling materials and ideas of what can be done in school				
5 (1 session)	Students present and reflect on their products and project outcomes	X				

4 Summary and conclusion

Young people are permanently surrounded and increasingly influenced by technology. As long as the subject "Technology" does not exist, Swiss schools and teacher education are required to integrate technology and engineering into related subjects or subject areas like "Nature and Technology", "Technical and Textile Design" or "Economy, Labour, Housekeeping". The analyses of subject areas, basic concepts and competency areas show that the specification of technological literacy in the Swiss curriculum "Lehrplan 21" differs quite remarkably from other conceptions.

Although "Technical & Textile Design" plays a key role in technology education as regards its subject and competency areas, the standing of the subject in compulsory education is quite low and STEM initiatives mainly focus on (or support) "Nature and Technology". In sum, the scientific approach to technology is promoted and the technical-creative approach is weakened. With the new subject "Economy, Labour, Housekeeping", at least some social and economic aspects of technology education appear in the curriculum.

As many studies show and teachers know, it is quite hard to arouse young people's interest in technology with theoretical approaches. Accordingly, an increasing number of science teachers use technical and creative gateways to technology (Guedel, 2014). To be able do so in a proficient way, they need to talk to and learn from professionals. Against this background, an interdisciplinary master's course for Swiss pre-service teachers that includes scientific, practical, creative, social and economic aspects seems to be a promising way of fostering technological interest and literacy in an extended context.

We do not know yet how exactly the master's course we outlined in this paper will be implemented, how many students from which subjects will opt for it, and what learning outcomes and experiences are to be expected. Still, something very encouraging has already happened: teacher educators from different subjects discuss and argue with each other, and broaden their understanding of technology education. This is of great value – if not to technology education, then definitely to the professional development of teacher educators.

References

Boerlin, J., Beerenwinkel, A., & Labudde, P. (2014). *Bericht Analyse MINT – Nachwuchsbarometer Schweiz. Das Interesse von Kindern und Jugendlichen an naturwissenschaftlich-technischer Bildung.* Basel: Pädagogische Hochschule FHNW.

D-EDK. (2016). *Lehrplan 21*. Retrieved from: www.lehrplan21.ch [05.05.2016].

England National Government. (2013). *National curriculum in England: design and technology program of study.* London: Department of Education.

Guedel, K. (2014). *Technikaffinität von Mädchen und Jungen der Sekundarstufe I. Untersuchung von Technikinteresse, Selbstwirksamkeitserwartung, Geschlechterrollen und Berufswünschen.* PhD thesis, University of Geneva, Switzerland.

Guedel, K. & Heitzmann, A. (2016). Naturwissenschaften in der Gesellschaft: Naturwissenschaft plus Technik. In S. Metzger (Ed.), *SWiSE – Swiss Science Education – Naturwissenschaftliche Bildung Schweiz*. Berne: Haupt.

Konsortium HarmoS Naturwissenschaften[+]. (2010). *Wissenschaftlicher Kurzbericht und Kompetenzmodell*. Retrieved from: www.edudoc.ch/static/web/arbeiten/harmos/harmoS_kurzbericht_neu.pdf [05.05.2016].

International Technology Education Association [ITEA]. (2007). *Standards for technological literacy: Content for the study of technology*. Reston: ITEA.

New Zealand National Government. (2014). *National Curriculum.* Retrieved from: nzcurriculum.tki.org.nz [05.05.2016].

Rossouw , A., Hacker, M., & de Vries, M.J. (2011). Concepts and contexts in engineering and technology education: an international and interdisciplinary Delphi study. *International Journal of Technology and Design Education, 21* (4), 409–424.

Schmayl, W. (2004). Vom Aufbau und von den Inhalten des Technikunterrichts. Teil 2: Die Inhaltlichkeit des Technikunterrichts. *Zeitschrift für Technik im Unterricht, 28* (111), 7–15.

VDI (2007). *Bildungsstandards Technik für den Mittleren Schulabschluss.* Duesseldorf: VDI.

An intervention into the teaching and content knowledge challenges of Technology teachers in Mpumalanga Province, South Africa

Mishack T Gumbo
University of South Africa
Department of Science and Technology Education
gumbomt@unisa.ac.za

The aim of this paper is to report the findings of the design-based research study regarding the challenges that Grade 9 Technology teachers face in the teaching and content knowledge of Technology in Mpumalanga Province, South Africa. Technology teachers in South Africa still struggle with the teaching of the subject since its inception in 1998. Few studies have been conducted to investigate this problem. Thus, this study contributes to this limited body of knowledge. The study was conducted as part of a collaboration between the newly established Mathematics, Science and Technology Academy (MSTA) under the auspices of Mpumalanga Department of Basic Education (MDBE), and Department of Science and Technology Education (Dept S&TE) at University of South Africa (Unisa), the purpose of which is to intervene in these challenges by providing in-service training to these teachers. The research question was: What are Grade 9 Technology teachers' teaching and content knowledge challenges which need intervention? Twenty teachers who participated in the focus group interviews (FGIs) were conveniently selected from the four districts whose teachers attended the workshop on 31 July 2015 to 1 August 2015 and 7-8 August 2015. The findings revealed that teachers faced challenges in the aspects of teaching Technology, how they experienced learners, having their needs met, and their expectations of the workshops. It is imperative for MSTA and MDBE to know what challenges Technology teachers grapple with so they can plan relevant professional teacher development which is informed by these challenges.

Keywords: Intervention, challenges, Technology teachers, teaching, content knowledge, professional teacher development.

Introduction and background

The aim of this paper is to report the findings of the study which explored the challenges that Grade 9 Technology teachers face in the teaching and content knowledge of Technology in Mpumalanga Province, South Africa. The implementation of Technology Education has attracted issue about teachers' knowledge of Technology (Stein, McRobbie & Ginns, 1999; Jarvis & Rennie, 1996; Mapotse, 2012). Reitsma and Mentz (2007), in their needs analysis study, found that Technology teachers needed to be developed in the following knowledge areas:

- Subject content knowledge and skills to be able to function as a knowledgeable Technology teachers;
- Pedagogical knowledge and skills to be able to function as a knowledgeable Technology teachers in the school environment; and
- Pedagogical content knowledge developed through adequate implementation and support in practice.

This matter is crucial considering the still under-qualified and unqualified teachers in the education system as a whole (Taylor & Vingevold, 1999; Department of Education, 2006; Mapotse, 2012). Studies on teacher development have found that many teachers are seriously lacking in pedagogic skills in supporting individual differences in learners (Laine & Otto, 2000; Kent, 2004).

Teacher development implicates PTD. PTD remains crucial for the effective implementation of the curriculum. PTD means improving teachers' skills and competencies required to produce outstanding learner results (Reading First, 2005). Teacher development in teaching and content knowledge is crucial for learner achievement (Shulman, 1986; 1987; Pikulski, 2000; Darling-Hammond, 2000). However, PTD in South Africa is accused of becoming nothing more than a mere state-funded skills development programme (Steyn, 2008:3). This accusation is made alongside low quality of teacher education (Bullough, 2001; Mewborn, 2001; Gore, Griffiths & Ladwig, 2004). Exploring Technology teachers' challenges prior to conducting the workshop in Mpumalanga Province was to ensure that the workshop and those to follow really benefit teachers more than they just be other state-funded projects. Teacher workshops have also been criticised for being brief, fragmented incoherent and decontextualised, and isolated from the classroom (Vonk, 1995; Villegas-Reimers, 2003). This issue is important in Technology Education especially considering the fact that teachers qualified in other subjects were asked to volunteer to teach the subject at its inception as there were not as yet qualified teachers in the subject. The depth and focus of training falls under spotlight. The current study helps to understand these issues through the challenges that teachers face.

The newly established MSTA in 2014 is tasked with training Technology teachers through in-service workshops (started in 2014) as an intervention strategy to develop their teaching and content knowledge. The Dept S&TE at Unisa participates in this project by partnering with MSTA – partnership started in 2015. One of Dept S&TE's main roles is to conduct research by way of evaluating and monitoring the impact of this intervention. Thus, professional teacher development (PTD) becomes the aspect of discussion in this theoretical section.

This study was framed in the model for PTD in Design and Technology (see figure 1) suggested by Stein, McRobbie and Ginns (1999). This model includes crucial areas about the subject matter of Technology Education which teachers should be competent in. Stein et al (1999) concede that planning for PTD should seriously consider teachers' existing beliefs and knowledge because that impacts on their perspectives and attitudes towards the innovation that should be inculcated, as well as the time, space and opportunity to experiment with ideas and to reflect on their experiences.
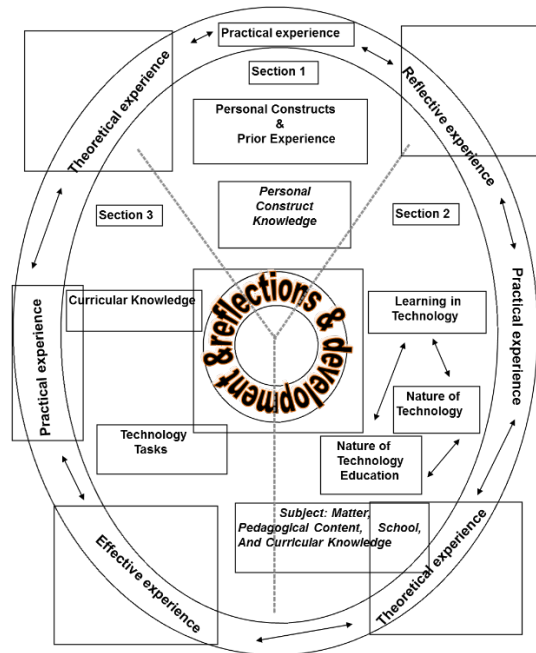
Figure 1: PTD in Design and Technology model (adopted from Stein et al., 1999)

Research design

Design-based research (Barab & Squire, 2004; Plomp, 2007) formed the impetus of this study. Researchers who aim for developmental goals focus on solving teaching, learning and performance problems in a body of theoretical design principles that can inform future development efforts (Reeves, 2000). The iterative design (Reeves, 2000) was adapted to illustrate the salient features of this design logic (refer to figure 2).

Refinement of problems, solutions and implementation of intervention into Technology teachers' teaching and content challenges
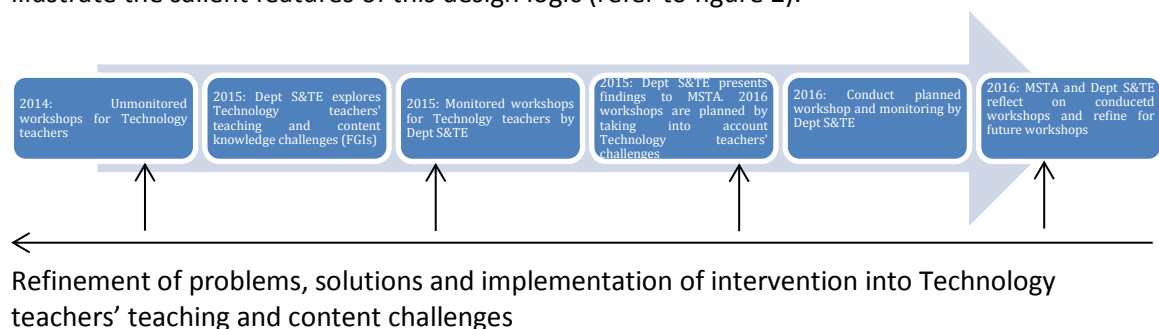
Figure 2: Design logic for monitored teachers' workshops (adapted from Reeves, 2000)

As it can be noticed, the data being presented here is are part of the whole design outlined in figure 2. Semi-structured FGIs were conducted in 2015 with select Grade 9 Technology teachers prior to beginning with the intervention workshop. Conveniently, through the help of the MSTA Technology official, six Technology teachers from Botlhabela District, six from Ehlanzeni District, four from Gert Sibande District and four from Nkangala District were selected to participate in this study. The selection was done at a common venue where a two-day workshop was to take place. The FGIs were conducted in a room reserved by the hotel and they lasted about 40 minutes with each of the four groups.

A semi-structured interview guide was designed prior to the workshop. It included the biographical and the interview questions. The biographical part gathered information on qualification, general teaching experience and specific Technology teaching experience. The main part of the interview guide gathered information on teachers' views about teaching

Technology, how they experienced learners, having their needs met, expectation of the workshops.

Analysis began during data gathering so that I could pre-establish patterns that were pre-eminent and to get an indication about possible saturation. Deeper reading of the data followed with resultant coding and theme identification.

Ethical clearance to conduct this study was granted by the Unisa and permission by the MDBE. The participants were asked to sign consent letters prior to their participation in the study. Teachers were duly informed about the purpose of the study prior to their participation and given a choice to participate or not to participate in the study. They were promised confidentiality and their permission to record the interviews was sought.

Findings

The findings about teachers' challenges were presented under the questions they were asked in the FGIs. Firstly, biographical information of teachers is presented in tables 1 and 2.

Table 1: Biographical information (Gert Sibande and Nkangala Districts)

Item	T1	T2	T3	T4
Gert Sibande District				
Qual	BEd	Dipl in Ed, BTech (Ed Man), BEd Hons	HED, STD (TE), N6	Nat Dipl
Service in yrs	3	11	26	8½
Service (TE) in yrs	3	8	17	6 mnths
Grd taught	8-9	7-9	8-9	9
Nkangala District				
Qual	BPEd, Postgrad (Publ Man), Postgrad Dipl (Man), Cert (HIV/Aids)	Dipl (Ed), Dipl (ICT), Cert (Bus Comp)	Dipl (Ed), BA, Cert (TE), Cert (Bus Comp), BTech Hons	Dipl (Ed), Cert (Maths & Scie), Dipl (IT)
Service in yrs	23	2	25	16
Service (TE) in yrs	2	1	16	4
Grd	8-9	7-9	4-9	8-9

Table 2: Biographical information (Botlhabela and Ehlanzeni)

Item	T1	T2	T3	T4	T5	T6
Botlhabela District						
Qual	SPTD, BEd Hons, ACE (Man), ACE (TE)	BSC Hon, Agric (Animal Scie)	SPTD	NDTE	STD, ACE (Man)	STD, ACE (Maths)
Service in yrs	20	6	26	20	20	14
Service (TE) in yrs	17	6	17	5	17	1
Grd taught	8-9	7-9	8-9	7-9	7-9	7-9
Ehlanzeni District						
Qual	BEd Hons	ACE	NT 6	STD	STD (Com	STD (Eco

Item	T1	T2	T3	T4	T5	T6
	FET (Tech), Dipl (Tourism)	(Maths), STD, BEd Hons (Maths), Cert (Maths)	(Electr Eng)	(Maths)	Subjects), ACE (TE)	& Acc), ACE (TE)
Service in yrs	4 mnths	14	20	24	4 mnths	12
Service (TE) in yrs	4 mnths	4	20	4	8	8
Grd taught	9	8-9	8-12	8-9	8-9	8-9

The findings show that many teachers have short service in Technology Education, which confirms the challenges that they have in the teaching of the subject. Since Technology Education was implemented in 1998, it could mean that those teachers who with more than 18 years of service in the subject (T3 from Ehlanzeni District) were teaching Technology related subjects in technical colleges prior to the introduction of Technology Education.

Teachers' views about teaching Technology
The findings under this category exhibited diverse views that teachers held about teaching Technology. One view was that "Technology is a very interesting subject even though there are contextual factors resource-wise". Very few schools were resourced satisfactorily whereas the majority of schools (rural schools) were terribly under-resourced. Another view was about Technology producing future professionals in the technology fields:

But moreover, this subject, Technology, because our country is forever becoming a better country and developing, by teaching Technology we need to get learners who are more inspired to become engineers because technology is about solving problems.

But some teachers felt that they were not competent enough in the teaching of the subject due to their low level of qualifications in the subject (also refer to tables 1 and 2):

I did my diploma in commercial subjects. So, now I went for ACE Technology. The problem which I have, I don't have the basics of Physical Science, and sometimes when I am supposed to teach where there are a lot of calculations in relation things which are happening in Physical Science I sometimes find it difficult even when I go out there to ask a teacher.

The content knowledge, I think it is better if we can have someone who is an expert like in Structures who have train us to have a deeper knowledge so that we can teach it better to our learners. I did Technology first in my STD. I never did it at High School level.

For some teachers, their teaching the subject was hampered by their not knowing how to use the smartboard that the Department of Basic Education has supplied their schools with:

In my case there are other things, now we are having like smartboards. Sometimes we must use them to teach these learners. I have no knowledge of that, even sometimes the practical part.

How the teachers experienced learners

A much prominent finding in this regard was the challenge that teachers faced of the high teacher-learner ratio, which was 62 learners per teacher on average put against teaching and learning activities and time available. It was stated in this regard:

Myself I just want to say something about the issue of overcrowding of the learners in class; the practical thing you can't do, the period there is not enough.

Teachers found it extremely difficult to teach Technology and manage learners under such circumstances, and felt that "maybe our classroom arrangement can change. We have small classrooms with 60 to 80 learners".

With Mpumalanga Province being predominantly rural, the findings revealed that teachers were teaching learners of poor and unemployed parents. This affected their learning in many respects. Furthermore, "in most cases they are struggling when it comes to drawings because some of them fail to see the top view, side view, even though we teach them". Learners also struggled to understand the subject because they lacked the basic understanding of mathematics for use in doing basic calculations in Technology:

We have a problem there with practical when it comes to the mathematical part, because Technology in almost every term there are calculations, calculation of voltage, resistance, current, Ohm's Law. Second term there is calculation of gear ratio, rpm, all those things when mathematics is involved, many learners because they do not have a good mathematical background.

Teachers made an effort to "involve other learners to explain in maybe using the local language instead of using English" to help facilitate learners' understanding of the subject because "some of them experience English as a language barrier".

Teachers' needs

The main need was resources. Teachers felt that learners "show interest in Technology but the problem is resources. Sometimes we depend on theory. As you said they are from rural areas, their parents are unemployed, pensioners". Faced with this challenge, teachers "wonder if it is possible for our government to provide the 3D machines to our schools. If ever you have a 3D printer you are able to draw that thing".

Some schools had close to no resources at all to use in the teaching of Technology – "I was so surprised last year when I was doing some practicals. Okay, I was teaching the Grade 9's. The only thing I found at school was a bulb. We actually think that it can be better for us as educators if we can have a Technology class where every resource is there, well equipped".

Teachers needed to be knowledgeable in the use of the supplied smartboards.

Teachers also needed help from their subject advisors as some (teachers) were only qualified in other subjects and direly needed more help in the teaching of Technology which they were less qualified in.

Teachers' expectations about the workshops

The main expectation was to be trained in how-to-do Mini-Pats. Mini-Pats are the design projects that teachers should teach learners which are contained in the CAPS (Curriculum and Assessment Policy Statement). Teachers' view is stated in this regard:

The newly introduced mini-Pat, many teachers and learners are struggling with this one. There are still more things to learn, teachers to know what is involved there. Most teachers see it as a monster, something difficult to do, and they don't know what to do.

Teachers felt that the time for the workshops already attended in the past was extremely short; "they should give us more time". When faced with time constraints "facilitators do not have time to explain and engage us as teachers". Teachers suggested options about more time: two more days to a week is ideal, every beginning of a term, during school holidays.

Teachers wanted to learn more about certain problem areas during the workshops. For example, "I was expecting us to be engaged in drawings. Besides learner not knowing drawing us as teachers also do not know these things. The two drawings which were included in the last examination, even me, I could not do those drawings".

The findings show a dearth of need about developing teachers' teaching and content knowledge. This is in confirmation of the findings of other studies. For instance, the finding that teachers aspire more time for the workshop supports Reitsma's and Mentz's (2007) claim, that Technology teachers' teaching and content knowledge needed attention. The fact that they are still under-qualified (see their Technology teaching experience in tables 1 and 2) (Taylor & Vingevold, 1999; Laine & Otto, 2000; Department of Education, 2006; Kent, 2004; Mapotse, 2012) increases their training needs, especially considering the fact that many of them were asked to volunteer to teach Technology at its inception in 1998. The training should also help the teachers about how they can deal with certain issues which surfaced from the findings, i.e. to integrate resources such as the smartboard, and to handle bigger number of learners they have in their classes.

Conclusion

The study reported in this paper presented the challenges that Technology teachers still battle with specific reference to Mpumalanga Province. This is despite numerous workshops that teachers and those in other provinces have undergone. The findings raises demands about careful thought which should be invested in the intervention of the teachers' challenges that MSTA in collaboration with Dept S&TE plan to conduct. Serious consideration should be given to workshops which last for at least a week, preferably during school holidays, highly interactive workshops rather than facilitator-centred. For example, as part of the learning activities, teachers could be scheduled to present during the workshops. MSTA should team up with lecturers from Dept of S&TE at Unisa who can contribute the teaching and content knowledge from academic trainer's point of view. Findings of the monitoring project should be heeded for the improvement of the intervention. Training the teachers in smartboard use should not be downplayed. MSTA should mobilise MDBE and other stakeholders for the provisioning of resources. MDBE should register teachers with higher education institutions such as Unisa to do Technology Education specific programmes starting from a diploma to a degree.

References
Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *The Journal of Learning Sciences*, *13* (1), 1–14.
Bullough, R. V. (2001). Pedagogical content knowledge circa 1907 and 1987: A study in the history of an idea. *Teaching and Teacher Education, 17* (6), 655-666.

Darling-Hammond, L. (2000). Teacher quality and student achievement: a review of   state policy evidence. *Education Policy Analysis Archives, 8* (1), 1-49.

Department of Education. (2006). *The national policy framework for teacher education and development in South Africa: More teachers; better teachers*. Pretoria: Government Printers.

Gore, J. M., Griffiths, T., & Ladwig, J. G. (2004). Towards better teaching: Productive pedagogy as a framework for teacher education. *Teaching and Teacher Education, 20*, 375-387.

Jarvis, T., & Rennie, L. J. (1996). Perceptions about Technology held by primary teachers in England. *Research in Science and Technological Education, 14* (1), 43-54.

Mapotse, T. A. (2012). *The teaching practice of Senior Phase Technology Education teachers in selected schools of Limpopo Province: An action research study.* Unpublished doctoral thesis, University of South Africa, Pretoria.

Mewborn, D. (2001). Teachers content knowledge, teacher education, and their effects on the preparation of elementary teachers in the United States. *Mathematics Education Research Journal, 3*, 28-36.

Plomp, T. (2007). *Educational design research: An introduction.* Paper presented at a Seminar on an Introduction to Educational Design Research. Shanghai, PR China.

Reading First. (2005). Why is professional development so important? *The Newsletter For The Reading First Program, Summer*, 1-12.

Reeves, T. C. (2000*). Enhancing the worth of instructional technology research through "design experiments" and other development research strategies.* Paper Presented at the International Perspectives on Instructional Technology Research for the 21st Century. New Orleans, LA, USA.

Reitsma, G., & Mentz, E. (2007). *Training of technology educators in South Africa: A model for short course in-service training*. Paper presented at PATT18 Conference. Glascow, USA.

Shulman, L. S. (1986b). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15* (2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57* (1), 1-21.

Stein, S. J., McRobbie, C. J., & Ginns, I. (1999). *A model for the professional development of teachers in Design and Technology*. Retrieved April 14, 2016, from www.aare.edu.au/99pap/ste99273.htm.

Steyn, G. M. (2008). Continuing professional development for teachers in South Africa and social learning systems: Conflicting conceptual frameworks of learning. *Koers, 73* (1),   15-31.

Taylor, N., & Vinjevold, P. (1999). *Getting learning right: Report of the president's education initiative project*. Johannesburg: The Joint Education Trust.

Villegas-Reimer, E. (2003). *Teacher professional development: An international review of the literature*. Paris: International Institute for Educational Planning.

Vonk, J. H. C. (1995). *Teacher professional development: An international review of the literature*. Paris: UNESCO International Institute for Educational Planning.

Technological education in France: the efficiency of tools from the functional analysis in the learning process for describing technical objects.

GUNTHER Fabrice
Aix Marseille Université
Marseille France
fabrice.gunther@laposte.net

CHATONEY Marjolaine
Aix Marseille Université
Marseille France
Marjolaine.chatoney@univ-amu.fr

Abstract

The study of technical systems occupies a central position in technological education. It allows for an understanding of the complexity of these systems in their multidimensional technological reality. We focus here on one method used to teach technology: functional analysis. The tools associated with this method are specific to technicians and engineers. They can be related to technical language. In secondary schools, teachers transform these tools into artefacts. The purpose of this transformation is to allow pupils to understand technical systems. But problems arise: the problem of transferring tools from an industrial world to a technological education; the problems of knowledge and reference; and the problems of appropriation and transformation of these artefacts by teachers and pupils. Since they add complexity, is learning these description methods relevant? How does the transmission of information to pupils happen? How do pupils use this information?

Our theoretical background includes the instrumental genesis, as described by Rabardel, which explains the place of the artefact in the teaching and learning process. This process is complex, so we think it is necessary to incorporate the way the activity is studied by Engeström, as well as the cognitive parts introduced by Bandura and Bruner. The analysis of students' reactions in social situations as they describe a technical object should help clarify the functioning of these mechanisms. We chose to stay in the classroom, with a quantitative methodology. We collected the pupils' productions during exercises. The resultant data are examined, and comparisons are made between the entry test and final productions for two different groups, one that has experienced a functional analysis initiation and the other that has not.

The results show that there are differences in the way the pupils apprehend technical systems, whether they had learned to use a tool of functional analysis or not. Differences also appear dependant on the pupils' level of study.

Keywords:
functional analysis, technology education, technical system, teaching-learning, artefact.

Introduction and context of the study

This paper follows a previous one presented in PATT21 in Marseille (Chatoney, Gunther, & Said, 2015). The purpose of the previous paper was to identify and characterize the use of functional analysis in the declared practices of teachers in secondary schools. It also contains details concerning the origin and the purpose of functional analysis. This time we want to analyze the way pupils might use a particular tool of functional analysis, the FAST diagram. FAST is an acronym for Functional Analysis System Technique. It allows for a global vision of a given system and has the advantage of rapidly and graphically describing that system in its entirety. A system consists of several elements thus the limit of the system could be defined. The interactions between the elements and with the environment as well as the retroaction on the system itself are others characteristics that define it.
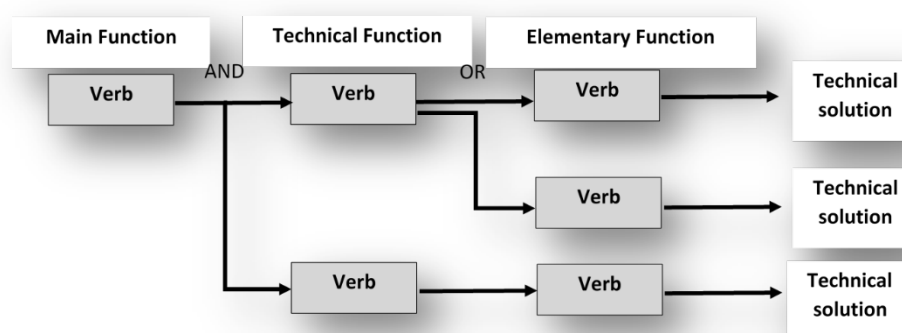
Figure 1: Generic FAST diagram

This representation is described in French standards (NF EN 12973) as a usual method of functional analysis. Originally created for the conception of a product it is firstly used for this purpose. After listing the different functions necessary to achieving the main function, solutions can be found and linked to the elementary function. Within our technology education context, FAST diagram is adapted to the needs of pupils who have just begun learning a new technical language. The benefits of such technical language have been shown by Leroux (2009). Dependent on the system, the diagram may not be an exhaustive description, but could permit a systemic and functional approach.

As functional analysis comes from the industry, it has to be adapted to be taught. The tool is then considered an artefact. For Rabardel (1995) instrumental genesis is based upon this kind of artefact. Functional analysis is instrumented and used by the teachers. The same process happens with the pupils. To achieve this, it is necessary to observe, learn, and understand each situation. This leads us to the cognitive aspect of the process: Bandura (1993) specifies that when observing, learning and understanding are present we can solve a problem, mentally or with actions. In our study we take into account these frameworks: the instrumental genesis, the theory of activity and the social cognitive theory. The methodology relies on them.

Methodology

Sample

Our experiment was conducted with 177 pupils aged 12 to 14. It is at this level that the study of technical systems is introduced as central knowledge in French technology education. The pupils belong to three different secondary schools from the area around Marseille, France. Three different teachers and six classes were involved. The secondary schools were chosen because they were representative of a social middle class, and the parents of the pupils belong to socio-professional categories close to the French average level.

Methodology for data collection

The fact that the sample concerns different schools allows to improve the validity of our data. And, in the same purpose, the exercises presented to the pupils were not described as school tests but as a research. It was also explained that the personal results would stay anonymous.

The first step was to take into account pupils' existent abilities to describe a technical system. Thus, our methodology began with an entry test. They had three minutes to describe a bicycle. The document provided was a picture of a bicycle with instructions to perform this exercise, the amount of time accorded, the purpose of the activity. They are familiar with this system, as it was introduced to them at a young age, and they had studied it in a lower grade. They shouldn't have significant problems completing this exercise.

Some more didactic works have shown that the research can be based on comparison (Groux & Chnane-Davin, 2009). The methodology described is inspired by the Solomon experiment plan, simplified with the use of only two groups (Van Der Maren, 1996). Thus, the next step, involved establishing two groups, one was taught how to describe a system with a FAST diagram and the other used a method based upon the description as it used to be done in science. This scientific description includes drawing with legends, arrows representing the flow of information, and is common to all actors in the field of education. The lesson consisted of a slide presentation with a recorded commentary, ensuring that the influence of the teacher was minimized between the three secondary schools. Two samples were shown and then the pupils had to do an exercise. This exercise was corrected with the proper method, functional analysis or science diagram, allowing for a reinforcement of the learning process (Astolfi, 2011). The systems chosen as samples were a spoon and a vacuum cleaner. For the exercise itself, the pupils had to describe a wheelbarrow. Although these systems appeared simple, without complex automatism, it is necessary to take into account that they are not as simple as they seem. Even the shape of a spoon is the result of different strength composition very diversified (Akrich, 1987).

After this lesson, a new system was introduced: a 3D printer. Pupils were told that they have to work within this system. The goal was for them to discover a new and unfamiliar system. A short movie describing the main functionality of the printer was shown twice. It was then up to the pupils to come up with a representation of this system.

As a way of observing the capacity of the pupils to describe this system, and not only to imitate, we waited one week before taking the next step. Not more time than this, so that they do not forgot the methods taught. The exercise was quite the same as the one for the entry test, only the system was different. The pupils had to describe how a 3D printer works to someone who doesn't know the system, in written form, and in three minutes.

Data processing

With reference to the descriptive characteristics of functional analysis, we can propose a theoretical model of data processing. We want to distinguish the pupils and to analyse different groups and the way they describe systems. Any system has a main function and an integrated components feature. In accordance with functional analysis, the various elements fulfill certain functions. To perform an accurate analysis, we can count, for a given pupil, how many functions and elements are quoted. The authors dealing with the systemic analysis agree to declare that the description of a system is based on an analytical or structural aspect and a functional aspect (Cambien & al, 2008; Donnadieu, Durand, Neel, Nunez, Saint-Paul, 2003). It is with these variables, the number of functions, and the number of elements used to describe a system, that we can know the status of the description. Depending on the time allowed in our methodology, we postulate that the maximum number of functions cited by students is 5, the maximum number of elements is about ten. We will use these maximum numbers in our model. This model allows for an approach to describing a system that takes into account the competences of a pupil. The following diagram presents the link between the number of functions on the horizontal axis, and the number of items quoted by the pupils on the vertical axis.
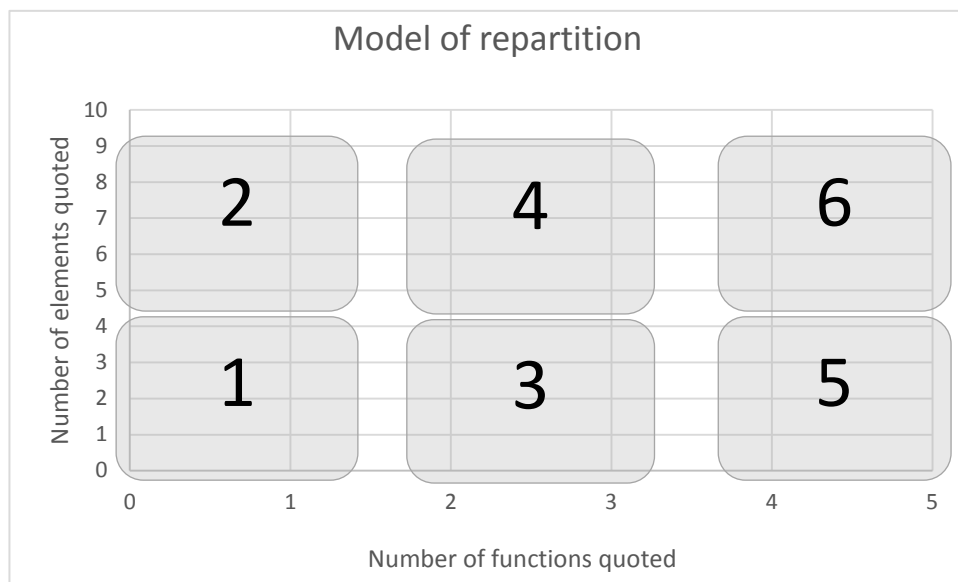
Figure 2: Model of pupils' repartition for the description of a system

Category 1 corresponds to a poor description. Number 2 is a description by elements with very low functional characterization. Category 3 is a little better than 2 but is still limited. Category 4 could be seen as mixed, with few elements and functions both. Number 5 represents a strong functional characterization but some elements are missing. Category

6 appears a good description; it is in this way that more complex systems can be analysed.

It is important to note that at this stage, the link between the function and the element quoted by the pupils is rather obvious. The pupils should be seen as beginners. In this short time, it is evidently not possible to complete the description, and only the main functions and elements can appear. This limits the wrong connections that pupils can make between one element and its function. To confirm this, we notice that it is common to analyse a system in terms of "function / structure / shape / element". This division is addressed and accepted by some authors (Chatoney, 2003; Ginestié, 2000; Graube, Dyrenfurth, & Theuerkauf, 2003).

As our hypothesis was about the efficiency of the functional, we suppose that if it is efficient in the academic frame it should be for all the pupils. If the pupils with in good academic standing have no significant problems using the tools they are taught, it will likely not be the same for pupils with academic difficulties. We introduce a new variable linked to the institution: academic level. Following Clanet's considerations (2013) and Talbot's as well (2013), we will distinguish three groups of pupils: the ones working at a high level, the ones at a low academic level, and the ones considered average. For Clanet and Talbot the pupils from the middle group will, after a lesson, join one of the other groups. For us this transfer from a group to another could be an indicator of efficiency. Our categorization to distinguish the three groups is based on all the marks the pupils obtained during the year.

Results, uses of functional analysis by pupils

According to our data processing for the entry test we have the following results.

	All the pupils	Pupils with good academic level (29 % of all)	Middle group (48 % of all)	Pupils with low academic level (23 % of all)
Category 1	43 %	38 %	46 %	40 %
Category 2	7 %	12 %	5 %	11 %
Category 3	31 %	30 %	31 %	31 %
Category 4	10 %	12 %	7 %	12 %
Category 5	3 %	3 %	3 %	6 %
Category 6	6 %	5 %	8 %	0 %

Table 1: entry test – distribution of the pupils according to model

The categories filled most are 1 and 3, which were described as poor and limited. At this stage, we notice that the description of a system is not dependent on the academic level of the pupil, and is not very effective. We also notice that the pupils operating at a lower school level are not capable of providing a strong description (category 6). It seems they haven't the tools to do it.

The 177 pupils were then divided into two groups. 104 were initiated to functional analysis and 73 were not. For the final description of the 3D printer, about half of the group initiated to functional analysis were able to reuse the tool to describe the system (53%). The other half either forgot to use it or found it too complicated or inadequate. In

addition, 5% of the non-initiated group were able to produce a representation using the tool. They should have learnt it before in the previous grades and found it powerful.

	All the non-initiated pupils	Pupils with good academic level	Middle group	Pupils with low academic level
Category 1	52 %	24 %	62 %	59 %
Category 2	13 %	12 %	13 %	12 %
Category 3	21 %	30 %	19 %	29 %
Category 4	6 %	12 %	3 %	0 %
Category 5	5 %	11 %	3 %	0 %
Category 6	3 %	11 %	0 %	0 %

Table 2: final test – distribution of the non-initiated pupils according to model

	All the initiated pupils	Pupils with good academic level	Middle group	Pupils with low academic level
Category 1	39 %	33 %	35 %	63 %
Category 2	2 %	3 %	0 %	0 %
Category 3	36 %	36 %	40 %	27 %
Category 4	7 %	17 %	4 %	0 %
Category 5	12 %	7 %	16 %	10 %
Category 6	4 %	4 %	5 %	0 %

Table 3: final test – distribution of the initiated pupils according to model

The first column shows that for all the pupils, category 3 increases by 15%. The group that has been initiated to functional analysis quoted more functions than the others, and the number of elements are quite the same for the two groups. That means that the pupils that were initiated associate an element with each function, but this is not the case with the non-initiated pupils.

We also notice that category 5 goes up to 12%, which means the pupils quoted more functions, 4 and 5, but they don't associate elements to these functions.

The results of the second column, pupils with good school results, shows that the learning of functional analysis doesn't provide any benefit to these pupils. When they are not initiated, the good pupils are better than the average ones in their class, but when they are initiated they are closer to this average; the difference between the first and second column of data in the second array is smaller than in the first array. These pupils already have a method of describing systems, mainly using text. They have little interest in changing this, as their method is successful.

In the third column of data, pupils with average academic results, the results are much more significant. The difference between the two arrays shows that these pupils take into account the functional aspect of the system. Category 1 is almost divided in two, and Category 2 decreases all the way to zero.

For the last column, the effect is not so important as it is for the middle group, but it is

worth noting that some pupils have a more functional approach, even though they have not connected elements to functions. These non-initiated pupils are in categories 1, 2 and 3, the initiated pupils are in categories 1,3 and 5.

If we compare these two arrays with the one from the entry test, the previous results are confirmed. The number of pupils that cannot describe the system increases for the group with a low academic level, whether they are initiated or not (category 1 increases from 40% to 59% and 63%). We must remember that the pupils are not familiar with the last system they described, the 3D printer, as they were with the first one, the bicycle. But for the middle group, the initiation seemed to be efficient. With no initiation, category 1 increased from 46% to 62%, while with initiation it decreased to 35%.

Conclusion

In conclusion, pupils tend to favour an analytical description of a technical system. If we introduce them to a functional approach, half of them use it willingly. However, the majority have difficulty combining functions and elements. Pupils with a good academic level, that means good marks, rarely change their approach and very few try to do it. Those who use this functional approach effectively are pupils who have average marks. If they have to describe a non-familiar system and have no tools to do it, they will mostly fail. If they have been initiated to functional analysis, the descriptions will be much better, and closer to the descriptions produced by pupils with good results. Among the pupils with a low academic level, some try to use functional analysis but only a few takes benefits for their systemic descriptions. To understand the structure that led the pupils to describe a system with both functions and elements, it is necessary to analyse the cognitive part of what happens. Some works are in progress to complete this study.

Few researches have been made on functional analysis in technology education. However, Krupczak (2010) concludes, as we do, that for novice or non-engineers, the functional analysis is a good framework to explain technology and to think in terms of functions. Considering general system thinking, Koski (2012) notices the benefits for the teacher and the primary school's pupils. Svensson (2015) shows that a few of these teaching could help "compulsory school's pupils to develop a basic grasp of technological systems". That is exactly what we have done here. Such results go in the same direction although the place of the technology is not exactly the same, it indicates that this kind of researches should certainly be continued and have to be fined-tuned.

Thinking in a systemic way is a complex activity, and its learning and teaching are particular. This work has to be done throughout technology education, and at this point this teaching only appears for high-level or specialised studies. It is certainly important that a future designer of technical objects takes into account all the dimensions of the system. But ordinary people as users, consumers and repairers will also have to deal with some decisions while using functional systems A progressive learning of technical language is necessary to make them efficiency and to improve the pupil's perception of systems.

Bibliography

Akrich, M. (1987). Comment décrire les objets techniques ? In *Techniques & Culture*. 49–64.

Astolfi, J. P. (2011). *L'erreur, un outil pour enseigner*. Issy-les-Moulineaux : ESF éditeur.

Bandura, A. (1993). Perceveid self-efficacy in cognitive development and functioning. *Educational psychologist*, *28*(2), 117‑148.

Cambien, A., & al. (2008). Une introduction à l'approche systémique : appréhender la complexité. Consulté à l'adresse http://lara.inist.fr/handle/2332/1431

Chatoney, M. (2003). *Construction du concept de matériau dans l'enseignement des « sciences et technologie » à l'école primaire : perspectives curriculaires et didactiques*. Thèse de doctorat. Aix Marseille : Université de Provence.

Chatoney, M., Gunther, F., & Said, F. (2015). Les outils de l'analyse fonctionnelle dans les pratiques enseignantes en technologie. *Review of Science, Mathematics and ICT Education.* DESECE : Université de Patras.

Clanet, J. (2013). L'efficacité enseignante, quelle modélisation pour servir cette ambition ? *Questions Vives. Recherches en éducation*, 6, 18.

Donnadieu, G. & al. (2003). *L'Approche systémique : de quoi s'agit-il ?* (Synthèse des travaux du Groupe AFSCET).

Ginestié, J. (2000). *Contribution à la constitution de faits didactiques en éducation technologique : curriculum vitae et publications*, HDR, Aix Marseille : Université de Provence.

Graube, G., Dyrenfurth, M. J., & Theuerkauf, W. E. (2003). *Technology Education: International Concepts and Perspectives*. Frankfurt am Main: Peter Lang Pub Incorporated.

Groux, D., & Chnane-Davin, F. (2009). *Méthodologie de la comparaison en éducation*. Paris : Harmattan.

Koski, M.-I., & de Vries, M. (2012). Primary pupils' thoughts about systems. An exploratory study. In *PATT 26 Conference; Technology Education in the 21st Century; Stockholm; Sweden; 26-30 June; 2012* (p. 253–261). Linköping University Electronic Press.

Krupczak, J. (2010). Using Functional Analysis as a Framework for Understanding Technology. In *American Society for Engineering Education*. American Society for Engineering Education.

Leroux, P. (2009). *Apprendre et enseigner la technologie par la robotique et l'informatique*. Québec : Éditions MultiMondes.

Rabardel, P. (1995). *Les hommes et les technologies : approche cognitive des instruments contemporains*. Paris, France : A. Colin.

Svensson, M., Ingerman, A., & Berglund, A. (2015). Teaching and learning system thinking in technology. In *29th PATT conference (Pupil's Attitudes Towards Technology)* (p. 404–409). Presses Universitaires de Provence.

Talbot, L. (2013). Les recherches sur les pratiques enseignantes efficaces. *Questions Vives. Recherches en éducation*, 6, 18.

Van Der Maren, J. M. (1996). *Méthodes de recherche pour l'éducation* (2. éd). Paris : De Boeck Université.

An assortment box of views: different perceptions of D&T's purpose and structure

Alison Hardy
Nottingham Trent University
UK
Alison.hardy@ntu.ac.uk

Abstract

Views about the value of Design and Technology (D&T) to students, the economy and society are diverse, occasionally exaggerated, and usually conflicting (for examples see Department of Education, 2013; Design and Technology Association, 2011 and 2015; Hardy, Gyekye, & Wainwright, 2015). For example: is D&T a subject with specialised knowledge? A subject that applies knowledge from other subjects? A vocational subject? A subject to meet the country's economic needs? Or a subject to develop good citizens?

These conflicting views were brought to the fore when the review of the English National Curriculum proclaimed that D&T has an insufficient disciplinary coherence (Department for Education, 2011). Strong, disciplinary coherent subjects have a clear form of knowledge and are favoured by the current UK government. Subjects with disciplinary coherence have strongly defined boundary between itself and other subjects (Bernstein, 2000), and strongly defined knowledge that is 'sacred … not ordinary or mundane' (Bernstein, 2003, p.73).

In response to this review, and other challenges, the Design and Technology Association (D&TA) has run two campaigns to 'fight' for D&T to be recognised as an important and essential part of the school curriculum (Design and Technology Association, 2011; 2015). But D&TA has not systematically investigated how D&T teachers and their students, the activators and receivers of D&T, perceive the subject's purpose and coherence. This paper uses Bernstein's (2000; 2003) concepts of classification and framing to analyse the perceptions of these two groups. Their assorted views are different to D&TA's campaign messages but as conflicting, and they concur with the curriculum review that D&T does not have a strong disciplinary coherence.

The conclusion suggests how this analysis could inform future D&TA campaigns and suggests that by addressing D&T's specialised knowledge and the contribution D&T makes to students 21st Century Skills is not lost but strengthened.

Key words: Bernstein, classification, design, knowledge, skills, technology education.

Introduction

Views about the value of Design and Technology (D&T) to students, the economy and society are diverse, occasionally exaggerated, and usually conflicting (for examples see Department of Education, 2013; Design and Technology Association, 2013; Hardy, Gyekye, & Wainwright, 2015). The Design and Technology Association (D&TA) has run two campaigns to 'fight' for D&T to be recognised as an important and essential part of the school curriculum (Design and Technology Association, 2011; 2015). Four reasons are given in the recent campaign for D&T's unique contribution to the curriculum: technological understanding, design thinking, evaluation of products and services, and skills for life. But with several underlying campaign themes the overall message is

confusing - is D&T a unique subject? A user of other subjects? A vocational subject? Or a subject to develop good citizens?

Both campaigns have been supported by notable engineers, designers and entrepreneurs and have argued that D&T contributes directly and indirectly to the economy, claiming D&T has 'much to offer across a wide range of career paths in engineering, manufacturing and the creative industries' (D&TA 2015, page 5). Whilst significant, these claims are unsupported by empirical evidence or much input from other stakeholders, such as D&T teachers, parents or students. With such a bias towards the instrumental value of D&T and a focus on influencing government ministers, it seems a missed opportunity not to involve those who can influence the ground support for the subject.

D&TA's arguments are intended to demonstrate that D&T makes a unique contribution to the curriculum, and is therefore an essential component of a broad and balanced curriculum.

Three events provide a context for these campaigns: a review of the National Curriculum in 2011, a rewritten National Curriculum in 2013, and the introduction of the English Baccalaureate (Ebacc) - a new performance measure for schools[1]. The curriculum review announced that D&T should only form part of a basic curriculum, in which the content should be informed by local context (Department for Education, 2011) based on the argument that D&T has an insufficient disciplinary coherence. Strong, disciplinary coherent subjects have a clear form of knowledge with facts and principles interpreted by the government as traditional academic subjects, such as maths and science. Disciplinary coherence can be seen as a subject that has a strongly defined boundary between itself and other subjects (Bernstein, 2000), with strongly defined knowledge, which is 'sacred, … not ordinary or mundane' (Bernstein, 2003, p.73).

These events have provided a space to debate the purpose of schooling and how subjects are defined (Young, 2011a; 2011b). Government ministers have lauded the work of Hirsch (2006) and Willingham (2009) who focus on the value of learning knowledge and facts, specifically 'general, all-purpose knowledge' (Hirsch, 2006, p.12), knowledge that forms part of a general education (Willingham, 2009), which Hirsch claims facilitates social integration and mobility. It would appear government ministers have interpreted 'knowledge' as facts – a 'general knowledge' (Gibbs, 2016; Gove, 2013; Morgan, 2015) not 'powerful knowledge' that is specialist, transformational and rooted in reality (Young & Muller, 2013); powerful knowledge is not everyday knowledge or non-school knowledge. Young's earlier writing on 'powerful knowledge' was acknowledged as influencing the outcome of the previously mentioned curriculum review (Young & Muller, 2013).

Bernstein's code theory

Bernstein developed a code theory to question how knowledge is distributed through the curriculum describing control, status, and pedagogy (Bernstein, 2000; 2003). This theory can be used to explore relationships between different subjects in terms of the boundaries between their content. For coding types of boundary strength he used the concepts of classification and framing.

Classification 'refers to the degree of boundary maintenance between contents' (2003, p.80); Bernstein used the term contents rather than subjects. So classification can refer

to the strength of boundaries between subjects. Where there are clear distinctions between the subjects there is strong classification, where classification is weak the distinction between content is blurred. Classification describes the relationship between the content, not what the content contains (Bernstein 2003).

Framing is about the degree of power and control teachers and students possess, of which there are two rules for regulating the framing that can vary independently (2000). The first rule relates to social order and forms of hierarchical relationships. Second is the rule of discursive order, which refers to the degree of control teacher and student possess over the 'selection, sequence, pacing and criteria of the knowledge' (Bernstein 2000, p.13) – pedagogical. In this rule the framing can refer to the 'strength of the boundary between educational knowledge and everyday community knowledge of teacher and taught' (Bernstein 2003, p.81) and a weak boundary exists when there is little distinction between these in the classroom.

Bernstein's theory extended to types of curricula; a collection curriculum has clear boundaries between curriculum subjects, an integrated curriculum has weak boundaries and the subjects have an 'open relationship' (Bernstein, 2003, p.79). Subjects with high status tend to have strong boundaries, belonging to a collection curriculum in which the knowledge is 'sacred, it is not ordinary or mundane' (2003, p.73). Earlier discussions about powerful knowledge, the curriculum review recommendations and the emphasis on strongly bound subjects in the Ebacc indicate a current policy preference for a collection curriculum.

Bernstein's vertical/horizontal discourse theory about the classification of knowledge defines sacred knowledge as esoteric and specialist, whereas mundane is knowledge that is common-sense knowledge acquired outside an institution through the family or community.

There are other views of curriculum content but here I want to briefly mention two other forms: vocational knowledge and skills. Skills can be defined as those that are useful in any or many work places (such as team working and problem solving) or skills to look after ourselves, for example how to cook or put up shelves at home – the D&TA campaign labels these as 'skills for life'.

This article uses these concepts to determine whether the participants classify D&T as a subject that has weak or strong disciplinary coherence.

Method
The research aim was to show that the view of D&T of the activators and receivers of D&T is also unclear and therefore has weak classification.
The views the participants held about the contribution D&T made to a general education were collected using interviews in two English schools (School 1 and 2) with students and two D&T teachers from each school. The interviews took place between March and May 2014, after the curriculum review and between the two D&TA campaigns.
The data were coded using a thematic approach (Saldaña, 2012), which summarised the participants' responses into codes that revealed the values they attributed to D&T (cf. Hardy, 2015). These values were grouped into three themes:
1. Responses that relate to the uniqueness of D&T as determined through analysis of the purpose of D&T as written about in official curriculum documentation since

1988 recent campaigns to save the subject and the vocational content that (could) lead to D&T related careers;

2. Responses about competency or skills, and
3. Responses that relate to other subjects and their content.

Findings

The total number of responses from both groups across the three themes was distributed as follows: 84 D&T specific (48%), 77 competency and skills (44%), and 15 other subjects (9%) (Table 1).

Table 5: Responses to all themes

	Total number of responses	D&T		Competency & skills		Other subjects	
		Total	% responses	Total	% responses	Total	% responses
Students	67	29	43%	34	51%	4	6%
D&T teachers	109	55	50%	43	39%	11	10%
Total	176	84	48%	77	44%	15	9%

Unique identity of D&T

The 84 responses coded as referring to the unique contribution of D&T were divided into two sub-themes: D&T related careers and businesses – 'Vocational curriculum', and D&T knowledge – 'D&T National Curriculum' (table 2).

Table 6: Responses related to D&T theme

	Total number of responses	Vocational curriculum		D&T National Curriculum	
		Total	% responses	Total	% responses
Students	29	18	62%	11	38%
D&T teachers	55	10	18%	45	82%
Total	84	28	33%	56	67%

Vocational curriculum was associated with the vocational and economic purpose of D&T.

'… it could help in the future if I want to become something like a designer.' (School 2 student);

'It creates a career option because when you start doing DT you learn if you would like to do this professionally or not.' (School 2 student);

The other category focused on designing, making and critiquing, features of every version of the D&T National Curriculum since 1990 with 56/84 (67%) responses, which was 32% (56/176) of the total responses.

'…rather than rushing into your practical you can design it and think it through rather than just doing it and then realising half way through it's not working' (School 2 student).

'You have to be really creative when you're doing your designs.' (School 1 student).

Competency and skills

The title for this theme belies the diversity of the participants' responses. Within this theme students are being trained to become competent in skills, tasks and practices (Bernstein 2003), some of which are generic skills such as problem solving skills and others that may derive from a sacred knowledge (for example heat induction) but have been reproduced by teachers as a task for students to learn for use at home (cooking a hot meal).

In this theme the 77 responses were subdivided into three groups, one about ways of learning (7/77), and the other two share ideas from the D&TA Campaign and overarching aims of the English National Curriculum (Department of Education, 2013) – (1) being an educated citizen (11/77) and (2) skills for life (59/77) (table 3).

Table 7: Responses to competency and skills theme

	Total number of responses	Ways of learning		Being a citizen		Skills for life	
		Total	% responses	Total	% responses	Total	% responses
Students	34	0	0%	1	3%	33	97%
D&T teachers	43	7	16%	10	23%	26	60%
Total	77	7	9%	11	14%	59	77%

Unsurprisingly only teachers commented on types of learning in D&T but the responses were not unique to D&T. For example School 2 teacher 2's view that in D&T 'they're not only using different parts of their brain but also parts of their bodies as well' could also refer to physical education and similar activities outside school.

In the theme 'being a citizen' participants talked about how D&T enables children to understand about other people and the impact of products and technology on themselves, others and the environment. None of these can claim to be unique to D&T, or even that they require a school education:

'[our teaching] makes people aware of saying right well I'm not going to put that can into that bin, I'm going to make it recycle and we recycle. So it's having a huge impact on the environment' (School 2 teacher 2)

'Even down to going shopping and understanding the psychology of trying to get the product across to people. So we've done a bit of psychology on how they get the students or the customers to be drawn into an inanimate object that is trying to sell itself' (School 1 teacher)

'Well I remember in the olden days you used to learn everything, cooking, sewing, DIY skills. If that wasn't available today I think that we'd become too dependent on technology and other things like that instead of doing it yourself.' (School 2 student)

The largest number of responses was in 'skills for life' (see table 4), a wide-ranging theme that included:

- students learning skills to look after themselves that meant they could do DIY, cook and sew (31/59, 54%);
- transferrable (generic) skills that employers are looking for, sometimes called 'soft skills' (22/59, 37%) and
- personal development, such as resilience and confidence (5/59, 8%).

Table 8: Division of skills for life theme

	Total number of responses	Skills to look after yourself		Transferrable skills		Personal development	
		Total	% responses	Total	% responses	Total	% responses
Students	33	22	67%	6	18%	5	15%
D&T teachers	26	10	38%	16	62%	0	0%
Total	59	32	54%	22	37%	5	8%

<u>Other subjects</u>
The two sub-groups in this section are about knowledge used in D&T that is from other subjects (8/15) and learning about materials (7/15), which draws on scientific knowledge (table 5).

Table 9: Responses to other subjects theme

	Total number of responses	Learning about materials		Links to other subjects	
		Total	% responses	Total	% responses
Students	4	0	0%	4	100%
D&T teachers	11	8	73%	3	27%
Total	15	8	53%	7	47%

'learning about new materials, how they work' (School 1 teacher 2)
'We use maths a lot, but we use it in a real way, so it's not scary, it's practical' (School 1 teacher 1)
'…like when you're doing graphics you have to draw first and then you do a drawing section, well that will help you in art for example, because then you don't have to learn in art…' (School 2 student)

Analysis and Discussion
As stated earlier Bernstein's classification and framing concepts are being used here to determine whether the participants classify D&T as a subject that has weak or strong disciplinary coherence, and weak or strong boundaries between specialist D&T knowledge and mundane knowledge. The interpretation of specialist D&T knowledge is lenient for analysis purposes; the author does not claim that learning about D&T related careers should be defined using Bernstein's definition of specialist knowledge or Young and Muller's (2013) view of 'powerful knowledge'.

The boundary between the uniqueness of D&T and other subjects appears from the data in table 1 to be clear-cut with a responses 84 attributed to the uniqueness of D&T and 15 to other subjects (85%/15% split), implying strong classification. On the surface the data shows a strong disciplinary coherence, but closer examination reveals it is a limited discipline according to these participants. Over half of the 56 responses about D&T knowledge referred to students learning to critique products and their impact on the

world's environment, which is only one aspect of the D&T National Curriculum content. Whilst the participant numbers and data are too small to generalise it does raise the question how the teachers and students recognise D&T as a strongly bounded subject with such a bias towards product analysis and evaluation, implying these participants have a narrow perspective of D&T's content and contribution.

The data in table 1 shows that for these participants D&T is a weakly bound subject in relation to mundane knowledge; this is similar between the two groups. They both place greater emphasis on D&T enabling students to gain knowledge for which D&T is not required. In other words this knowledge can either be learnt at home or in clubs and events outside school. There is a weak boundary between the D&T specialist knowledge and competency in a range of skills and tasks. Therefore the framing is weak but there is a strong horizontal discourse (Bernstein, 1999). But there are occasions when competency becomes specialist D&T knowledge:

 'School 2 teacher 1: I guess every design - well I would have thought every design has its purpose. So you've got to think about how a product is going to be used [*competency*].

Facilitator: Does that come from D&T? Or is that something that D&T contributes?

School 2 teacher 1: Yeah, I think it does because I think if they're looking at items and how they can be modified and changed and developed and ripped apart and made again in a different way [*specialist knowledge*]. Yeah, I think it does come from designing and D&T.' (School 2 teacher 1)

Comparing the values ascribed by the two participant groups exposes some expected anomalies. Given the students' age (13-14 years old) and schooling stage (the year they select which subjects to specialise in for their exams) it is not surprising they focus more on the instrumental values of D&T, such as employment (62% students compared to 18% teachers) and skills for life (97% to 60%). But the emphasis teachers place on D&T helping children become a good citizen (10/43 responses), particularly in comparison to the students' responses (1/34) is surprising. Again these differences indicate a weak framing but this time in relation to the second rule and selection of the knowledge, which Kelly (2009) differentiates between the planned and received curriculum – just because a teacher intended students to learn about people's differences does not mean this is what the students did learn.

The teachers' responses (18%) do not reflect D&TA's most recent campaign that emphasises the contribution D&T makes to the economy by supplying people with STEM expertise. There are other differences between the teachers and the campaigns, and even though this is a small group and the data were collected two years ago leaves me to question how in tune with the teacher's views the campaign is today? D&TA might argue that their campaign is not aimed at teachers but if they do not consider the values teachers ascribe to D&T their campaigns might not have the hoped for classroom impact.

The students' responses are also at odds with the campaign agenda. Almost a third of their responses are about skills to help them look after themselves, with many specifically mentioning learning how to cook, an area that is no longer part of the D&T curriculum or qualification. It is the author's view that it is the students who need persuading to see the value of D&T as it is written in the National Curriculum and promoted by D&TA, and as future parents of the next generation of students will have the greatest influence on their values and curriculum choices (Eccles & Wigfield, 2002; Harackiewicz, Rozek, Hulleman, & Hyde, 2012).

Conclusion

It must be acknowledged this is only a small study and unusually attempts to use curriculum theory to analyse the perceptions of teachers and students. However even with such a small group it can be seen there is an assortment of views of the purpose and value of D&T, which has implications for any attempt to influence the views of those both inside and outside classroom.

These teachers and students held a narrow perspective on what is the 'sacred' and specialised D&T knowledge, and emphasised how students learnt to become competent in skills, practices and tasks in D&T. With the current government's focus on specialised knowledge this leaves D&T at risk of continued exclusion from a general education for all students. The D&TA campaigns have not addressed either the subject's disciplinary coherence or specialised knowledge, but focussed on several messages that do not clearly address the government's agenda. A suggestion is for D&TA to look at the government's standpoint on knowledge if planning future campaigns fighting for D&T's place in a general education for all students. Even if D&TA want to emphasise the 21st Century skills gained by students in D&T they need to address the centrality of knowledge (Rotherham & Willingham, 2009).

This study is part of a PhD study and follows on from the pilot study reported at previous conferences (Hardy, Gyekye, & Wainwright, 2015; Hardy, 2013) and journal paper (Hardy, 2015).

Note

1. The Ebacc measure the number of students in a school that achieve a good grade in five 'core academic subjects' (Department for Education, 2016), maths, English, a science, history or geography, and a language.

References

Bernstein, B. (1999). Vertical and horizontal discourse: An essay. *British Journal of Sociology of Education, 20*(2), 157-173.

Bernstein, B. (2000). *Pedagogy, symbolic control and identity: Theory, research, critique* (Rev ed... ed.). Lanham, Maryland: Lanham, Maryland : Rowman and Littlefield.

Bernstein, B. (2003). *Class, codes and control vol.3: Towards a theory of educational transmissions* Routledge.

Department for Education. (2011). *The framework for the national curriculum. A report by the expert panel for the national curriculum review.* (). London: Department for Education.

Department of Education. (2013). *The national curriculum in England Framework document (july 2013)*. London: Department of Education.

Design and Technology Association. (2011). *'We believe in design and technology' what do you believe in? the design and technology association manifesto for design and technology education*. Wellesbourne, Warwickshire: The Design and Technology Association.

Design and Technology Association. (2015). Designed and made in Britain...? Retrieved from http://bit.ly/1n1vm9J

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*(1), 109-132.

Gibbs, N. (2016). *What is a good education in the 21st century?*. Hild Bede College, Durham University: Department for Education.

Gove, M. (2013). *Michael Gove speaks about the importance of teaching*. Policy Exchange: Department for Education.

Harackiewicz, J. M., Rozek, C. S., Hulleman, C. S., & Hyde, J. S. (2012). Helping parents to motivate adolescents in mathematics and science: An experimental test of a utility-value intervention. *Psychological Science, 23*(8), 899-906. doi:10.1177/0956797611435530 [doi]

Hardy, A., Gyekye, K., & Wainwright, C. (2015). What do others think is the point of design and technology education? *PATT29 Plurality and Complementarity of Approaches in Design & Technology Education,* Marseille, France. 217-224.

Hardy, A. (2013). Starting the journey: Discovering the point of D&T. *PATT27: Technology Education for the Future: A Play on Sustainability,* Christchurch, New Zealand. 222-228.

Hardy, A. (2015). What's D&T for? Gathering and comparing the values of design and technology academics and trainee teachers. *Design and Technology Education: An International Journal, 20*(2), 10-21.

Hirsch, E. D. (2006). *The knowledge deficit: Closing the shocking education gap for american children*. Boston: Houghton Mifflin Company.

Kelly, A. V. (2009). *The curriculum: Theory and practice* (6th ed.). London: Sage.

Morgan, N. (2015). *Nicky Morgan: Why knowledge matters*. Carlton Club, London: Department for Education.

Rotherham, A. J., & Willingham, D. (2009). 21st century skills: The challenges ahead. *Educational Leadership, 67*(1), 16-21.

Willingham, D. T. (2009). *Why don't students like school?: A cognitive scientist answers questions about how the mind works and what it means for the classroom* John Wiley & Sons.

Young, M. (2011a). What are schools for? *Educação, Sociedade & Culturas,* (32)

Young, M., & Muller, J. (2013). On the powers of powerful knowledge. *Review of Education, 1*(3), 229-250.

Young, M. (2011b). The return to subjects: A sociological perspective on the UK coalition government's approach to the 14–19 curriculum. *The Curriculum Journal, 22*(2), 265-278. doi:10.1080/09585176.2011.574994

Technology Education and Informal Learning: Technology in the Swedish Leisure-Time Centre as Boundary Object

Magnus Jansson, Department of Social and Welfare
Studies
Linköping University
Sweden
magnus.jansson@liu.se

Maria Simonsson, Department of Social and Welfare
Studies
Linköping University
Sweden
maria.simonsson@liu.se

Per Gyberg, Department of Thematic Studies,
Environmental Change
Linköping University
Sweden
per.gyberg@liu.se

Jonas Hallström, Department of Social and Welfare
Studies
Linköping University
Sweden
jonas.hallstrom@liu.se

Abstract

A majority of Swedish children between six and nine years old attend afterschool activities in a leisure-time centre, *fritidshem*, until their parents finish work for the day. Leisure-time centres are characterised by "educare" activities, that is, both educational and care-related activities and thus both formal and informal learning settings. The centres are part of the Swedish educational system and activities should be related to the national curriculum for the compulsory school. The centres are right now in an interesting transition which will lead to the introduction of more formal learning activities, for instance, in technology, at the same time as virtually no research has been carried out on technology activities in the centres. The aim of this paper is therefore to study the role of technology in activities in leisure-time centres. The results are drawn from field work conducted in three Swedish leisure-time centres. The observations focused upon the daily activities in the leisure centres, specifically activities where technology play a central part. The data collection was completed with interviews with teachers. We use the concept of boundary object to analyse the technological activities. The findings indicate that there is a special technology education that emerges in the context of the leisure-time center – *leisure-time technology education* – at the intersection between informal and formal technology learning, which ranges from the informal play-related construction of Lego and wooden blocks to the more formal computer instruction. The amorphousness of leisure-time technology – the fact that children can choose what they want it to be and what to learn –points to it being a boundary object with a very open interpretative flexibility.

A majority of Swedish children between six and nine years old attend afterschool activities in a leisure-time centre, *fritidshem*, until their parents finish work for the day. Leisure-time centres are characterised by "educare" activities, that is, both educational and care-related activities and thus both formal and informal learning settings (Hantson & van de Velde, 2011). The centres are part of the Swedish educational system and activities should be related to the national curriculum for the compulsory school (Skolverket, 2011). The centres are right now in a transition which will lead to the introduction of more formal learning activities, for instance, in technology, at the same time as virtually no research has been carried out on technology activities in the centres. The aim of this paper is therefore to study the role of technology in activities in leisure-time centres. We pose the following research questions: What is the role and meaning of technology in the activities? What is the nature of teacher intervention and context dependence in the activities? In technology education the context is crucial for understanding what a particular activity represents, which is why a study of *fritidshem* as an institution between school and leisure can generate new knowledge not only about said centres but also technology education itself (Björkholm, 2015; de Vries, 2005).

Background and previous research

The focus of the research on leisure-time centers conducted over the past 10 years is described by Falkner & Ludvigsson (2016) to be largely limited to three main areas; the historical development of the centers, the inclusion of them in the education system, and, lastly, what Haglund (2009) describes as a shift from a "discourse of care to a discourse of knowledge" (p. 28) in the centers, a result of the inclusion in the schools. Only a few studies have focused on what is done in activities in the leisure-time centers (cf. Falkner & Ludviksson, 2016; Klerfelt & Haglund, 2014; Närvänen & Elvstrand, 2015). Hjalmarsson & Löfdahl (2015) studied children's involvement in computer games in which they were trained to handle different social experiences, as opposed to more result-oriented learning in the schools. The study highlights what Saar (2014) argues is a distinction between, on the one hand, school-centered and formal learning, and what can be described as leisure-centered, informal learning where the child's social management is focused, on the other. Falkner (2007) writes about the meaning of digital games in the centers' activities and asserts that the games have both a social and cognitive significance. Kane, Ljusberg & Larsson (2015) are puzzled about whether teachers are always a step ahead and have the skills to facilitate children's learning when playing. They believe that there is a risk that the teachers routinely offer "Lego time" (p. 19) and other activities instead of thinking about the purpose of the play. In sum, the inclusion of technology in activities in the leisure-time centers still seems to be largely within an informal discourse of care, despite the clear general trend toward a more formal discourse of knowledge. Thus, as Jensen (2011) points out, learning is often the result of children's active choice to participate in voluntary activities.

There is quite extensive research on informal learning in preschools and schools, from which can be concluded that technology can be learnt in play in various ways, from technological role play to language acquisition and concept learning to cognitive modelling (Milne, 2013; Parker-Rees, 1997; Pramling Samuelsson & Asplund Carlsson, 2003; Turja *et al.*, 2009). The research on informal technology learning outside of school settings is scarce. It is discussed by Hantson & van de Velde (2011) in relation to Belgian youth organisations, in which design game interventions were carried out in the Creativity, Design and Innovation at Work Project (COI@work). The authors conclude that

the interventions worked well but that the formal, educational element could easily marginalize the informal gaming aspects (p. 128). In science education there is a greater body of research about informal learning, and it deals with, for instance, informal contexts such as museums, informal organisations such as youth organisations like the Scouts, or informal digital tools such as computers and tablets (Jarman, 2005; Osborne & Dillon, 2007). So although there are rather similar phenomena to activities in the Swedish leisure-time centers in the international literature, the centers are at the same time quite unique in their mix of formal and informal learning settings.

Theory and methodology

In this study we use the concept of *boundary object* as a theoretical tool to understand the role of technology in activities in leisure-time centres. According to Star & Griesemer (1989) boundary objects are:

[…] both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use. These objects may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is a key process in developing and maintaining coherence across intersecting social worlds (p. 393).

We argue that technologies, more specifically technologies in the leisure-time centres, constitute such boundary objects and that these objects are of importance to understand how different social worlds are maintained. The way we use it, the boundary object concept offers, or triggers, certain possibilities for meaning which are not necessarily coherent. The "object" refers to a pre-organized entity of meaning possibilities, and the "boundary" illustrates the coexistence of different social worlds that are made possible through the object. Boundary objects are by definition flexible and heterogeneous by offering multiple "stuff of action" (Star 2010 p. 603).

The results are drawn from field work conducted in three Swedish leisure-time centres. The observations focused upon the daily activities in the leisure centre, specifically activities where technology play a central part. The three centres differed, this both from a socio-economic but also a geographical aspect. The selection was based on the idea of variation between the big city, small town and rural area, which also had a socio-economic logic. The study has an ethnographic base with both open (inductive) and focused observations (see Charmaz, 2014). The observations have been continuously recorded as field notes and also as various memos. Creating memos, according to Glaser (1978), is to memorize, record and then follow up the different ideas that come out of the data (Robson, 2011; 2015).

The research approach used in the study is inspired by Grounded Theory Methodology, GT (Charmaz 2014). The GT steps of the analysis have to some extent been followed, specifically the continuous use of theoretical selection and a process of comparative approaches. The process has involved making data collection in parallel with a comparison between the codes and concepts in the encoding process, where the encoding also provides an indication of where the focus should be in the next data collection. The analysis has aimed to explain, specify and define the various categories. Finally, additional data have been obtained in order to achieve theoretical saturation. The

final step of the analysis involves creating different themes (Charmaz, 2014; Wilson, 2012; Corbin & Strauss, 1990).

Results
Building and construction

The results show that activities involving technology are often more or less spontaneous in the children's informal free play, in which they build or make different kinds of constructions with Lego or wooden blocks. The kind of construction material they use and what they build are naturally constrained by the available material in the leisure-time centre, but Lego and various kinds of wooden and plastic blocks are ubiquitous in centres all over Sweden. Since the time for play is considered "free" – it can be seen as a continuation of similar preschool activities that most children have engaged in when younger (cf. Hallström *et al.*, 2015) – the teachers keep a low profile, only intervening when they have to or are asked to. The following field note shows an informal learning situation with Lego blocks:

My idea was to observe and listen for what the boys said to each other, and how the teachers acted around the Lego construction. However, the boys did not speak but were fully occupied with their designs. The teachers were not present by the group of boys building either. A girl I talked to earlier during snack time now came up to me where I sat with the boys. The girl, Anna, sat near me and looked on, she then said that she would also build Lego. The girl was then accompanied by another girl who also chose to build with Lego. […] None of the children commented on each other's building and it was only Anna who constantly showed me what she was building. Anna had chosen to use a Lego plate to build on, and on the plate she had chosen to build an enclosed park bench. On the park bench sat two Lego figures and beside stood one more Lego figure. Anna talked about the figures on the park bench and said that one of them was a girl and the other was a boy. I asked what the figure who stood beside was. Anna replied that it was a park guard, "one that guards so that nothing is lost". I asked one of the boys nearest to me what he was going to build. He replied that he was making a "weapon machine". Anna said that the Lego girl must have hair and reached once again between the five boys, and began looking for a hair to the figure. Anna then took up a brown hair and put it on the female figure; she had also found another body to this figure. The other girl at the Lego construction, Lena, showed me her construction. It was a bit hard to see what it would be, but Lena said that it was a fantasy world (field notes, 9 October 2015).

The example above illustrates how the girls get inspired by the boys' Lego play, and pick up some Lego blocks from the already ongoing construction activity. The Lego material gives rich opportunities for design and construction, with countless combinations of shapes and colors, and the "products" are often used in play activities.

In this local play practice the pupils thus create meaning to their Lego constructions, which are often accompanied with stories and names, a kind of narrative discourse. In the example above, we can see two types of narrative styles; the girl's story is based on elements related to relations between the Lego figures, while the boy's story is of a more descriptive and informative nature. One can argue that these narrative styles can be linked to gender aspects. The contingent character of Lego construction in the free play is therefore evident in the sense that, for instance, a gendered use of technology can be seen where girls express interest in relations, emotions – and hair – and boys weapon machinery. Technology as a boundary object allows for different social worlds depending

on whether you are a boy or girl, and different Lego blocks are used to express this meaning (Star & Griesemer, 1989).

In the field notes below the teachers are more active in supporting the children's construction with wooden blocks, although gender still plays a significant part in that only boys are involved and they construct buildings, a railway track and a bridge:

After the snacks, I went back to the room. On the floor of the hall was now four boys building with *kappla* [a kind of building block]. […] I sat down with them and listened to the children's interaction in the construction of various buildings. The boys were building during great silence, while both children and adults gently came and went past them. The boys built buildings, houses, and open and closed pagodas. One of the boys looked at the various buildings and said he would make a railway between them. He had built a house, but thought that a railway was something he wanted to build. Kicki came by and asked questions about the various construction sites, such as what the various buildings would be, why a railway? The boy who built tracks replied that he wanted the buildings to be connected by a railway [understood as establishing communication between them]. [...] At a third table sat a boy and built an arched bridge of wood. The material contained a complete set of different finished pieces as well as a support for building the vault. It looked to be about thirty different pieces of arch bridge in front of the boy. Two teachers were standing around the table and they let the boy try, but also gently supported him in how he could think about getting ahead to get the vault together and to get the construction to hold. Finally, he figured out how he would use the supportive arch to build the vault, and which bits that could fit into the structure (field notes, 6 November 2015).

In the field notes above it is evident that there was a clearer focus on learning technology when the teachers intervened, that is, they changed the informal activity into a more formal learning situation by utilizing the play-related context of the blocks. This extract thus shows that technology as a boundary object can combine different social worlds of playing with social worlds of formal learning.

Computers and tablets
Technology can also be seen in more formal educational settings in which the children learn how to use digital tools such as computers and tablets. There is often a connection between the informal and formal settings in that the children, for example, use tablets to film their wooden block constructions or to watch Youtube clips of such constructions and discuss their solidity. In the following field notes the children were enrolled in a very formal learning situation as they got to try out very basic operations on a laptop, in the very same classroom that they had had their school teaching earlier the same day:

Several of the children had now entered the gaming site and tried different games. K walked around the classroom and helped the children who raised their hands. Other children shouted to each other, "damn good game I'm about to show you." More children now seemed to have a problem. K asked a boy "what did you do, which button did you press?". K told the children that he just "goes to S first, will come when you hand up hands". A boy in the corner of the classroom sat long with his hand up, then told K that K did not come to him. Other children in the classroom continued shouting to each other "this I have been playing at home." K came past me and said that the children are not accustomed to computers, "they only play on the iPad at home". It is not the same thing

since "they do not know how to do with buttons and mouse" (field notes, 31 August 2015).

Although this learning situation is formal, the very basic learning content as well as the way the teacher and children handle this show that it is yet not a school setting. The freedom of choice for the children, for example when accessing online games, is thus typical of activities in the leisure-time centers. On the other hand, the focus on laptops might be seen as at least an attempt to introduce a more formal aspect of ICT learning since the object is to learn how to use a more established technology with greater capacity of carrying out formal activities, for instance, writing documents or carrying out calculations. The capacity of the laptop to combine the social worlds of informal and formal learning and to trigger different actions on the part of the children is crucial here.

Concluding discussion

In different practices, different "objects" are used to trigger certain stuff of action and meanings. A shopping cart in the store, for example. Even though the stuff of action in this example can be seen as obvious, the shopping cart can also be a boundary object when a child sitting in it pretends that the cart is a fast driving car hunted by dinosaurs. Even though the social worlds exemplified here are very different they actually cooperate around at least one "property". In this case the property is that the cart is moving. It is this property that makes the object a boundary object.

In a learning practice, different objects are sometimes used with the same obvious means to learn as the shopping cart is for shopping. In the same way, the very special setting of leisure-time centres offers objects related to leisure and play. This means that the possible stuff of action is much broader in the sense that it is not necessarily related to the practice of learning. There are also possibilities to use other technologies – and using them in a way that does not have another purpose than leisure.

The results of this study point to a very important characteristic of technology, succinctly pointed out by Lewis and Zuga, that it is in the "very nature of technology" that there is a "variety of roles and purposes that technological activity can serve" (Lewis and Zuga, 2005, p. 6). We would thus argue that there is a special technology education that emerges in the context of the leisure-time center. We could call it *leisure-time technology education*, at the intersection between informal and formal technology learning, which ranges from the informal play-related construction of Lego and wooden blocks to the more formal computer instruction. Of course, as pointed out in the research overview, the play in itself is a kind of learning, and as such the learning potential of leisure-time activities is transferrable to other educational settings where play occurs such as preschools, day-care centres, and youth organisations.

In all these activities there is a distinct leisure-time quality, primarily in the form of free choice of technology and object of learning. This amorphousness of leisure-time and play-centered technology – the fact that children can choose what they want it to be and what to learn – thus points to it being a boundary object with a very open interpretative flexibility (Leigh Star & Griesemer, 1989; Bijker, 1995). The freedom and interpretative flexibility can be seen as restricted by gender structures but it is at the same time at the boundary of the object that the social world of boys and girls meet and share the same technological object.

References

Bijker, W.E. (1995). *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*. Cambridge, MA & London: MIT Press.

Björkholm, E. (2015). *Konstruktioner som fungerar. En studie av teknikkunnande i de tidiga skolåren.* Diss. Stockholm: Stockholm University.

Charmaz, K. (2014). *Constructing grounded theory: A practical guide through qualitative analysis*. (2nd edition) London: SAGE.

Corbin, J. & Strauss, A. (1990). Grounded Theory Research: Procedures, Canons and Evaluative Criteria. *Zeitschrift fur Soziologie, jg.19, Heft 6, Dezember 1990* (pp. 418-427).

de Vries, M.J. (2005). *Teaching about technology: An introduction to the philosophy of technology for non-philosophers*. Dordrecht: Springer.

Falkner, C. & Ludvigsson, A. (2016). Fritidshem och fritidspedagogik – en forskningsöversikt. *Forskning i korthet nr 1* 2016. Sveriges Kommuner och Landsting och Kommunförbundet Skåne.

Glaser, B. (1978). *Theoretical Sensitivity*. San Francisco: The Sociology Press.

Haglund, B. (2009). Fritid som diskurs och innehåll. En problematisering av verksamheten vid afterschool-programs och fritidshem. *Pedagogisk forskning i Sverige, 14*(1).

Hallström, J., Elvstrand, H. & Hellberg, K. (2015). Gender and technology in free play in Swedish early childhood education. *International Journal of Technology and Design Education, 25*(2), 137-149.

Hantson, P. & van de Velde, D. (2011). Technological Literacy in Youth Organisations. In Marc J. de Vries (Ed.), *Positioning Technology Education in the Curriculum.* Rotterdam: Sense Publishers.

Hjalmarsson, M. & Löfdahl Hultman, A. (2015). Confirming and resisting an underdog position – leisure-time teachers dealing with a new practice. *European Early Childhood Education Research Journal, 23*(4), 434–443.

Jarman, R. (2005). Science learning through Scouting: an understudied context for informal science education. *International Journal of Science Education*, *27*(4), 427-450.

Jensen, M. (2011). Informellt lärande i fritidshemmet. In A. Klerfelt & B. Haglund (Eds.), *Fritidspedagogik. Fritidshemmets teorier och praktiker*. Stockholm: Liber AB.

Kane, E., Ljusberg, A.-L. & Larsson, H. (2013). Making Magic Soup – The facilitation of play in school-age childcare. *International Journal of Play, 2*(1), 7–21.

Klerfelt, A. & Haglund, B. (2014). Walk-and-Talk Conversations: a Way to Elicit Children's Perspectives and Prominent Discourses in School-Age Educare. *International Journal for Research on Extended Education, 2*(2).

Lewis, T., & Zuga, K.F. (2005). *A Conceptual Framework of Ideas and Issues in Technology Education*. Arlington, VA: Technology Teacher In-Service Education & National Science Foundation.

Milne, L. (2013). Nurturing the designerly thinking and design capabilities of 5-year-olds: Technology in the new entrant classroom. *International Journal of Technology and Design Education, 23*, 349–360.

Närvänen, A.-L. & Elvstrand, H. (2015). What is Participation? Pedagogues' Interpretative Repertoires and Ideological Dilemmas Regarding Children's Participation in Swedish Leisure-time Centres. *International Journal for Research on Extended Education, 3*(2), 5–23.

Osborne, J. & Dillon, J. (2007). Research on learning in informal contexts: Advancing the field? *International Journal of Science Education*, *29*(12), 1441-1445.

Parker-Rees, R. (1997). Learning from play: Design and technology, imagination and playful thinking. In IDATER 1997 conference (pp. 20–25). Loughborough: Loughborough University. http://hdl.handle.
net/2134/1458.

Pramling Samuelsson, I. & Asplund Carlsson, M. (2003). *Det lekande lärande barnet – i en utvecklingspedagogisk teori*. Stockholm: Liber.

Robson, C. (2011; 2015). *Real World Research*. Chichester: John Wiley & Sons Ltd.

Skolverket. (2011). *Läroplan för grundskolan, förskoleklassen och fritidshemmet 2011*. Stockholm.

Star, S.L. & Griesemer, J.R. (1989). Institutional Ecology, "Translations" and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science, 19*(3), 387–420.

Star, S.L. (2010). This is not a boundary object: Reflections on the origin of a concept. *Science, Technology & Human Values*, *35*(5), 601-617.

Turja, L., Endepohls-Ulpe, M., & Chatoney, M. (2009). A conceptual framework for developing the curriculum and delivery of technology education in early childhood. *International Journal of Technology and Design Education, 19*, 353–365.

Let's have a look behind the code
The Big Mathematics Day 2016 (Netherlands) about coding without computer.

Mieke Abels, Vincent Jonker, Ronald Keijzer & Monica Wijers
Utrecht University, Freudenthal Institute
the Netherlands
m.j.abels@uu.nl, v.jonker@uu.nl, r.keijzer@uu.nl, m.wijers@uu.nl

Abstract

Students in Dutch primary schools spend quite some time working on mathematics. The average lessons however are limited to relatively short interactive introductions of new content; the rest of the time pupils spend on paper and pencil work. There is little time for mathematical reasoning and problem solving that inspires both students and teachers. In 2004 the Freudenthal Instutute of Utrecht University started an annual event (the 'Grote Rekendag', the Big Mathematics Day) to promote inquiry learning in the mathematics lessons of primary school. In 2016 we organized this event with the theme "Let's have a look behind the code", a theme inspired by the activities from 'CS unplugged' and by other educational ideas and the upcoming interest in coding and programming for young children. Using interviews (pupils age 9-12 and teachers) and a questionnaire we investigated what pupils and teachers liked about the theme and the activities and what they think they learned from these. Results show that teachers and pupils liked the activities. Teachers indicated that their pupils learned about coding and procedures, and less about how a computer works.

Keywords

computer science; inquiry learning; primary education; mathematics education

Theoretical background

The Big Mathematics Day (www.fi.uu.nl/en/wiki/index.php/Big_Mathematics_Day) is a whole day event for primary schools based on the view of 'Mathematics as a human activity' and the approach of 'Realistic Mathematics Education' as the central pedagogical and didactical concepts.

Realistic Mathematics Education, or RME, is the Dutch answer to the world-wide felt need to reform the teaching and learning of mathematics (Van den Heuvel-Panhuizen, 2000; Gravemeijer, 1994). The roots of the Dutch reform movement go back to the early seventies when the first ideas for RME were conceptualized. It was a reaction to both the American "New Math" movement that was likely to flood our country in those days, and to the then prevailing Dutch approach to mathematics education, which often is labeled as "mechanistic mathematics education."

In RME mathematics is seen as a human activity: pupils guided by the teacher re-invent and construct mathematical concepts, tools and ideas (Freudenthal, 1991). Problem solving, mathematical thinking, reasoning and communicating are core activities. Another aspect of RME is the intertwining of learning strands, not only within mathematics but also between mathematics and science and technology. See also the related concepts of mathematical literacy (Jablonka, 2003), techno-mathematical literacy (Hoyles et al, 2003) and scientific literacy (De Jong et al, 2001)

In the so called 21st century skills documents (Trilling & Fadel, 2009; Edens et al, 2010) emphasis is placed on providing pupils with a new set of competencies – besides

foundational skills - that will enable them to adapt to an ever-changing environment (Gresnigt et al, 2014). These include analytical and problem-solving skills, communications skills, interpersonal and collaborative skills, global awareness, and financial, technological (Cunningham, 2009) and civic literacy.

In recent years more and more value is placed on computer related skills for everyone. Knowing how a computer works, basic understanding of (computer) coding, computational thinking and learning the basics of programming, according to this view should be part of the curricula, starting in primary school at an early age (Mishra & Koehler, 2006; Kuhlemeier & Hemker, 2007). These skills together are part of what is nowadays labelled as *digital literacy*. According to Wikipedia (en.wikipedia.org/wiki/Digital_literacy) a digitally literate person will possess a range of digital skills, knowledge of the basic principles of computing devices, skills in using computer networks, an ability to engage in online communities and social networks while adhering to behavioural protocols, be able to find, capture and evaluate information, an understanding of the societal issues raised by digital technologies (such as big data), and possess critical thinking skills. Gui & Argentin (2011), considered digital skills not only in terms of actual know-how but also as a measure of the awareness of the technical and logical structures beneath digital environments.

On a worldwide scale more and more classroom activities and materials are being designed to implement digital literacy in (primary) education (Libow Martinez, 2014). The materials of Computer Science unplugged (http://csunplugged.org) show that a lot of the aforementioned skills can be also learned without a computer. The activities introduce students to Computational Thinking through concepts such as binary numbers, algorithms and data compression, without having to use computers or programming.

Inspired by these ideas we combined mathematical thinking as part of mathematical literacy and computational thinking as part of digital literacy, to design a whole day of activities for primary school students, with both emphasis on having good classroom activities and good support for the teacher (a manual that was sent to all schools about 5 weeks prior to the Big Mathematics Day 2016).

The activities
We designed activities for the Big Mathematics Day 2016 in which students (grades 4 to 6, age group 9 to 11) 'invent' and inquire how they can instruct machines (computers and robots) to carry out specific tasks. The emphasis is on the concepts behind coding, rather than staritng with coding on the computer. In most tasks students do activities like ordering, planning, sorting and (de)coding. In all cases they try (and learn) to think in steps that a computer would take, and use and find ways to describe these steps using symbols, schemes, patterns and structures. In this respect mathematical and digital literacy are almost similar. Most activities can be used in different grades, albeit on different levels.
We discuss four typical activities that all deal with coding and we illustrate these with exemplary work from pupils.
   1. Colour by Numbers (*no computer*)
   2. Live Turtle (*no computer*)
   3. Coding your Pin (*no computer*)
   4. Building with blocks (*computer*)

Activity 1 - Colour By Numbers

In this paper and pencil activity pupils explore how images are displayed and coded, based on the pixel as the building block (see Figure 1). In particular, the great quantity of data in an image means that we need to use compression to be able to store and transmit it efficiently.

The representations in the grid use numbers to indicate which pixels are turned on and which are turned off (black or white). There are two different versions: one where each pixel is coded individually using 0 or 1 and one using codes for ranges of pixels, like 1-3-1 alternating white and black (see Figure 1).
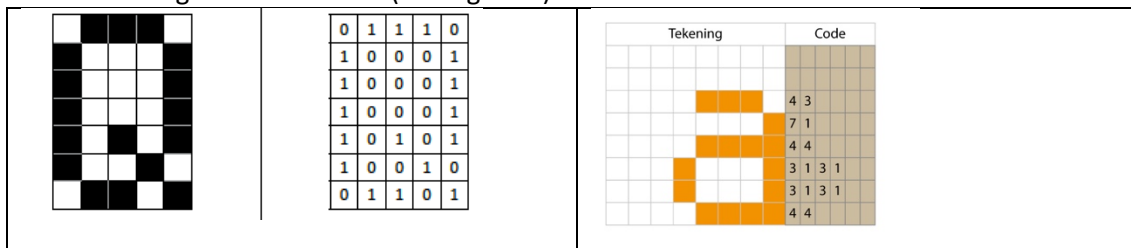
Figure 1. Two ways of coding

Students explore different ways of coding, and invent new ways to shorten codes or to include colouring. They design drawings, code them and check in pairs if their codes work out well,
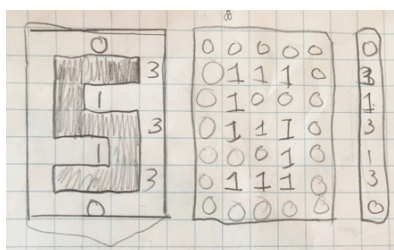
Figure 2. Student work of the activity Colour by Numbers

The shortenend way of coding invented by this student (Figure 2) is not really 'working'. The student may not yet have fully understood what is essential, When you condsider the code in the array of numbers on the right (0,3,1,3,1,3,0) it is impossible to get to the 'S' as the decoded result. This array only holds the number of pixels you need to color in each row; what is missing for each row is the starting point of the range of colored pixels. By exploring their own coding systems, students discover what are essential characteristics to make the coding work. The example presented here comes from: csunplugged.org -> image-representation. Similar activities are published as logical puzzles in journals or on webiste.

Activity 2 - Live Turtle

This activity, also done without the use of a computer, is the 'embodied' version of turtle logo 'programming language' (Papert, 2003). This activity is presented in two versions: one for the lower grades and one for the upper grades. In the lower grades pupils guide a robot through a labyrinth on paper using arrow-codes. In the upper grades pupils work in pairs on their own designs. One pupil draws a simple shape and writes a program coding it using commands like 'turn 90 degrees, walk 10 steps', etc.). The other child 'runs' the program by performing each 'step', one step at the time, like a robot on the schoolyard (Figure 3). If this is done correctly the drawing of the first pupil appears again.
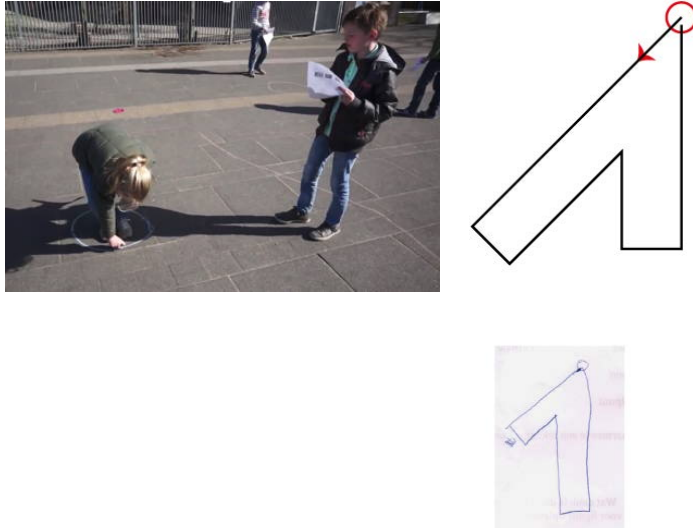
Figure 3. Students working together in the Live Turtle activity and their drawing

Even for students in the upper grades this turned out to be a difficult activity. They often drew seemingly simple shapes (Figure 3), that turned out to be complicated to code. Especially the commands for making turns were hard for them. This can be understood if we realize that to draw an angle of 45 degrees, as in the upperpart of the shape in figure 3, the command is not 'turn 45 degrees, but 'turn 135 degrees'. The outer angle is the 'turn-angle'.

Acrivity 3 – Coding your PIN

This activity for the higher grades, draws on the use of binary numbers. A square divided in 8 segments is presented. Each segment in the lower left half of the square represents the number 1, 2, 4 or 8 (see Figure 4). By colouring the appropriate segments each digit 0-9 can be represented as a pattern. The lower left square in figure 4 is coded to represent the number 5. Colouring segments in the upper right half of the square is used only to generate a nice pattern and cause confusion in order to make decoding harder.

Figure 4. Instructions and example for coding a PIN

Students use four squares to code a PIN. This activity was one of the favourites, partly because students could use creativity as well as thinking and reasoning. Of course students also had to explore this new way of coding. This also means they had to find out how and why they needed only four segments - numbered 1, 2, 4 and 8 - to code all digits. Pupils also reasoned about other numbers that could be coded with 1, 2, 4 and 8 and they found out how to extend this way of coding by adding one or more extra segments, in order to extend the range of numbers to code.

Activity 4 - Building with Blocks

This activity (with a computer) is based on the popular small application 'building with blocks' used in many classrooms for primary education in the Netherlands (www.fi.uu.nl/toepassingen/28432/). In this version pupils can 'automate' the building by programming it. They can create their own programs using commands with 'coordinates' to build exciting shapes on the computer (Figure 5).
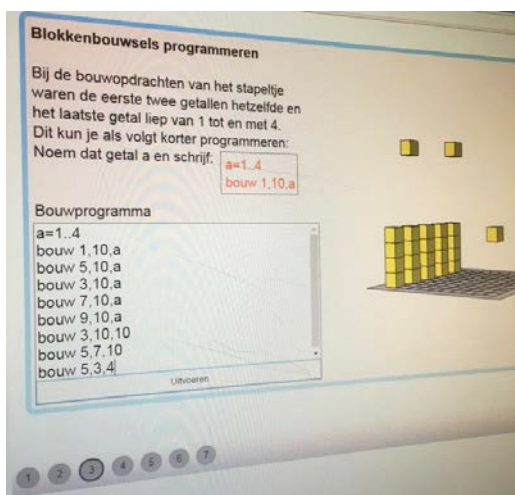
Figure 5. Student creating a 'building' by coding

In the example (Figure 5) the student is discovering the role of a variable/parameter, something new to most children age 11-12. The interface is easy and there is immediate feedback on the screen.

Methodology

We observed in three different schools participating in the Big Mathematics Day (a researcher was present during the activities), and interviewed both students and teachers in order to get an idea what they understood and liked about the tasks.

We also designed a questionnaire for teachers with the following questions (among others).

Table 1 - Questions used from the online questionnaire of the Big Mathematics Day 2016

	Question	Type
1	How many students in school?	open
2	Rate the activitiy in grades 5-6 (age 11-12), with a number 1 to 10	rate 1-10
3	Students have learned about procedures (rate 1 to 10)	rate 1-10
4	Students have learned about coding (rate 1 to 10)	rate 1-10
5	Students have learned about how computer work (rate 1 to 10)	rate 1-10
6	Overall impression (What is your opinion about the day, and the activities)	rate 1-10

For the questions 2 to 6 there was also the possibility to react in an open field.

Results

Students enjoy to work with the activities from the Big Mathematics Day, and get a better understanding of how computer programs are responsible for subsequent activities in a task. Teachers have difficulties in supporting their students because the content of the tasks is also new to them, and they try to find a different, more open and supporting approach to guide the children in their discoveries. Let's have a closer look at the data that came from the online questionnaire (N = 293 schools, see Table 2) and the observations/interviews in the three schools that were visited by researchers.

Table 2 - Data from the online questionnaire of the Big Mathematics Day 2016

	Results (N=293 schools)	N	Average	SD
1	How many students in school?	278	242	135
2	Rate the activity in grades 5-6 (age 11-12), with a number 1 to 10	270	7,8	0,9
3	Students have learned about procedures (rate 1 to 10)	284	7,4	1,1
4	Students have learned about coding (rate 1 to 10)	286	7,8	1,0
5	Students have learned about how computer work (rate 1 to 10)	270	7,0	1,7
6	Overall impression (What is your opinion about the day, and the activities)	289	7,9	1,0

Dutch schools for primary education differ in size (Question 1, with an average of 242 students per school, standard deviation of 135). For this research it is simply a fact that during the Big Mathematics Day 2016 about 65 thousand students (age 6 to 12) participated in the activities (about 17 thousand students age 11-12).

The overall impression of the Big Mathematics Day is that teachers (and students) enjoyed the activitivies of the Big Mathematics Day (Question 2, score 7,8). This is in line with the previous Days that were organized (from 2004 onwards).

Students have learned about procedures (Question 3). Some reactions (from the open field of Question 3):

- "It was good to see that children work together and then learn how to solve the posed problems following the procedures"
- "The 'smart' children (children that like new problems) are better prepared for this kind of activity. Especially when the activities are completely new to them."

Students have learned about coding (Question 4). Some reactions (from the open field of Question 4):

- "They have learned what coding is and especially designing your own code is a strong approach."
- "Sometimes the students were quick in discovering and explaining to each other how coding works"
- "Some tasks were really difficult for the children"

Students have learned about how computers work (Question 5). This is a little lower than Question 3 and 4, but still a good score. Some reactions (from the open field of Question 5):

- Children nowadays do have more devices to work with (laptop, tablet, phone) so they already have important experiences
- The activities point at 'how the computer work' and that is enough for this setting

In the analysis of Questions 4 and 5 we saw different responses from teachers where they point out that the activities were 'too difficult'. In the interviews we found that this observation is a mix of what the students gave back as a response and the behavior of the teacher. Some of the teachers are less involved in 'more scientific subjects' and they also have difficulties with the 'more open structure' of the didactics (inquiry learning). More 'exploration space' and discussion and interaction for the students means that the teacher sometimes only has to follow the findings of the students and to support them and give additional feedback, and this approach can differ in subject and quality.

This last observation (sometimes it is too difficult for student and teacher) is part of the whole approach of the Big Mathematics Day. It is also meant as a source for new didactical approaches and for new content for challenging and engaging lessons.

Question 6 gives the general feedback that teachers were really involved in the activities of this day, by scoring quite high for the 'overall impression'.

Conclusions

The approach described (coding activities for students age 9-12, during a whole morning, mainly without computer) gives a good introduction for learning about coding and understanding procedures and rules. For most teachers it meant a first step in their lessons in the area of computers and coding, and of course this activity must get a follow-up in a wide range of other activities (some materials of the Big Mathematics Day are published by the Utrecht University in the online repository of classroom materials for STEM, www.freudenthal.nl -> english, and we see a little rise in the amount of users of this kind of materials).

An important issue to be discussed with teachers but also with teacher trainers is the question if extra attention to (computer) coding must be given in the mathematics lesson. With this example of the Big Mathematics Day we hope to have given an example of how you can make a connection between mathematics education and coding. This approach is only going to work if this is also part of the textbooks used in primary education.

This approach of inquiry learning in the area of coding must get a follow-up in teacher training (for both new and experienced teachers). In the Netherlands this will get more attention in the next few years.

References

Cunningham, C. M. (2009). Engineering is elementary. *The Bridge. Linking Engineering and Society, 39*(3), 11-18.

De Jong, O., Savelsbergh, E. R., & Alblas (Eds.). (2001). *Teaching for scientific literacy: context, competency, and curriculum*. Utrecht: Utrecht University, Faculty of Sciences, Freudenthal Institute.

Drijvers, P., Doorman, M., Boon, P., Reed, H., & Gravemeijer, K. (2010). The teacher and the tool: instrumental orchestrations in the technology-rich mathematics classroom. *Educational Studies in Mathematics, 75*(2), 213-234.

Edens, K. M. (2010). Preparing Problem Solvers for the 21st Century through Problem-Based Learning. *College Teaching, 48*(2), 55-60. doi: 10.1080/87567550009595813

Freudenthal, H. (1991). *Revisiting Mathematics Education. China Lectures*. Dordrecht: Kluwer Academic Publishers.

Gravemeijer, K. P. E. (1994). *Developing realistic mathematics education.* CDbeta press, Utrecht. Retrieved from http://www.fisme.science.uu.nl/toepassingen/20014/ (FIsme Scientific Library 14)

Gresnigt, R., Taconis, R., Van Keulen, H., Gravemeijer, K., & Baartman, L. (2014). Promoting science and technology in primary education: a review of integrated curricula. *Studies in Science Education, 50*(1), 47–84. doi: 10.1080/03057267.2013.877694

Gui, M., & Argentin, G. (2011). Digital skills of internet natives: Different forms of digital literacy in a random sample of northern Italian high school students. *New Media & Society, 13*(6).

Hoyles, C., Noss, R., & Kent, P. (2003). Techno-mathematical literacies. Retrieved July 17, 2013, from www.ioe.ac.uk/tlrp/technomaths

Jablonka, E. (2003). Mathematical literacy. In A. J. Bishop, K. Clements, C. Keitel, J. Kilpatrick & F. K. S. Leung (Eds.), *Second International Handbook of Mathematics Education* (pp. 75-102). Dordrecht: Kluwer Academic Publishers.

Libow Martinez, S., & Stager, G. (2014). *Invent To Learn. Making, Tinkering, and Engineering in the Classroom*.

Mishra, P., & Koehler, M. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record, 108*(6), 1017–1054.

Papert, S. (2003). MicroWorlds EX. Retrieved from http://www.microworlds.com/

Trilling, B., & Fadel, C. (2009). *21st Century Skills: Learning for Life in Our Times*. Hoboken, NJ: John Wiley & Sons.

Van den Heuvel-Panhuizen, M. (2000). Mathematics education in the Netherlands: A guided tour. Freudenthal Institute Cd-rom for ICME9. Utrecht: Utrecht University.

Van Galen, F., & Jonker, V. (2013). *Experimenteren in de rekenles. Combineren van rekenlessen met lessen wetenschap & techniek*. Utrecht: Kenniscentrum Talentontwikkeling, Wetenschap & Techniek. Universiteit Utrecht.

Learners' Conceptions of Techno-Risk Tolerance

Manne Kallio[1] and Mika Metsärinne[2]
[1]University of Helsinki, Faculty of Behavioural Sciences, Department of Teacher Education
University of Helsinki, Finland
manne.kallio@helsinki.fi
[2]University of Turku, Faculty of Education, Department of Teacher Education
Rauma, Finland
mika.metsarinne@utu.fi

Abstract

The research task was to explore learners' conceptions of risk in Technology Education (TE) using the Techno-Risk Tolerance Questionnaire (T-RTQ). As zero risk is impossible to achieve some risk must be tolerated. Knowledge and understanding of technological production activities and sciences are needed in defining a tolerable level of risk. The teacher has a responsibility to guide learners in avoiding harmful risks while encouraging them to take beneficial risks. Success in production activities encourages learners towards new challenges while the risk of failing is set into right proportion. Innovative production activities include taking ingenious risks when exploring the limits and potential of the individual as well as the surrounding environment.

The conceptions of learners were assessed using the T-RTQ. The participants (n = 102) were 9th grade pupils of TE in compulsory education schools in Southern and Western Finland. The analysis took place in two phases. First, the internal consistency of the T-RTQ was tested and secondly, the results were compared to a previous survey n = 120 (subsample of 393 total). The fit indexes showed good fit between the model and the data. Techno-Risk Tolerance was measurable with the T-RTQ. Techno-Risk can be increasingly hidden in embedded systems and networks so pupils require more education in risk awareness in their technological activities. Further research should be carried out on both beneficial and harmful risks in order to avoid over-emphasizing harmful risks. The key ideology of the late 20th century Safety Education was achieving zero risk but Safety Education of the 21st century should be aimed to educate to prepare for uncertainty of Techno-Risk.

Keywords: Techno-Risk, Techno-Risk Tolerance Questionnaire (T-RTQ), Safety Education

Introduction

In the late 20th century, pursuing safety was adored in society. The development culminated into the idea of absolute safety, the so called Zero Risk Ideology which finally led to avoiding Techno-Risk and taking responsibility of it which then made Techno-Value difficult to achieve. As zero risk is practically impossible to achieve, safe can't mean the same as harmless. However, this was a popular definition until recently (Reason, 2008, 265; comp. Shrader-Frechette, 2003, 188–189). Uncertainty means that the break of safety is always possible (Hansson, 1999, 539). Techno-Risk Tolerance is required to continue action despite of the uncertainty.

One of the research tasks of this study was to re-test the Techno-Risk Tolerance Questionnaire (T-RTQ). The questionnaire was developed and modelled in the Safety Sense Project (Kallio, 2014) with a series of measurements representing the key-elements of learners' conceptions of Techno-Risk Tolerance. Other questionnaires of the Safety Sense Project were the Risk-Responsibility Questionnaire, the Techno-Value Questionnaire, the Techno-Risk Questionnaire and the questionnaires of risk covers and risk revealers, all with the same variables.

Learner-Centred Learning takes place when education focuses on survival in the technological world and constructing an even more viable technological life-world. Achieving innovativeness requires taking risks as innovativeness and risk are inter-correlated. The learner explores the limits and potential of him/herself and the surrounding environment when he/she tests new ideas. In a learner-centred culture, the learner must take ingenious risks as success is not certain. Even though the teacher has the responsibility to guide learners in avoiding harmful risks, ultimately the learner makes his/her own decisions on the risks at hand. The teacher's instructions and answers encourage and limit the potential of the learner but the learner's conception of his/her own Techno-Risk Tolerance is the determining factor when exploring the technological world.

The research questions were:
1. Is the Techno-Risk Tolerance Questionnaire (T-RTQ) valid and reliable for measuring learners' conceptions of Techno-Risk Tolerance?
2. What kind of conceptions of Techno-Risk Tolerance do learners have compared to previous results?

Theoretical Background

The presence of risks increase as the value achievable through technological activities increases or decreases – Techno-Risk increases as Techno-Value increases but aiming for lower Techno-Value also increases Techno-Risk. Therefore, both should be optimized. Technological production activities increase well-being as long as Techno-Risk remains below Techno-Value (see marked area in figure 1).
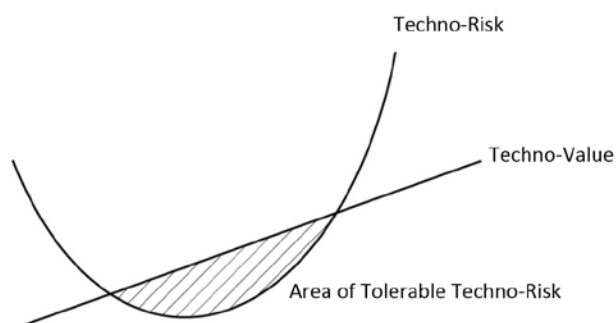
Figure 1. The Area of Tolerable Techno-Risk (Kallio, 2014).

As the level of safety approaches zero, the risk of a safety breach increases infinitely. This is the Highest Tolerable Level of Risk (HTLR). At this point, it is no longer worthwhile to pursue Techno-Value further at the expense of Techno-Risk increasing. On the other

hand, aiming for minimal Techno-Risk means lower Techno-Value. If a low level of Techno-Value is aimed for, Techno-Risk will increase before the HTLR is ever reached. New risks are faced when pursuing safety through reducing activity. Both ends of the scale are open and safety leads to well-being.

Technology Education (TE) includes a proportional amount of risk. If no value can be gained from an activity, no risk should be taken but if great value can be achieved, a higher level of risk should be tolerated. The HTLR is determined again and again as production activities progress or as new tasks are started.

A tolerable level of risk is not the same as an acceptable level of risk and risks should still be reduced (Hollander, 1997, 112). A tolerable level of risk can't be measured but must be decided (Lowrance, 1976, 75–76) which leads to ethical considerations (Shrader-Frechette, 1992; Hansson, 1999, 542). The tolerable level of risk in TE is determined by comparing the value that may be achieved through production activities and the probabilities of risks that may rise from the activities. The learner's possibilities to participate in society and to use technology in their lifelong learning should also be taken into consideration. Generally, taking controlled risks in school is safer than facing the same risks in less controlled environments later in life.

The risks within TE can be assessed both qualitatively and quantitatively. The qualitative dimension represents the severity of the outcomes of risks while the quantitative dimension represents the probabilities of the risks. Risks can be comprised of many different, possibly risk-free components that together form an unbearable risk. A quantitatively measurable risk can be so improbable that it becomes statistically insignificant (Shrader-Frechette, 2003, 188–189). The quality of risk should be assessed subjectively when the probability of a risk can't be determined (Shrader-Frechette, 1992). Subjective assessment means that every learner has their own conception of a tolerable level of risk. Whether risks are assessed according to speed, costs, productivity or Techno-Value, the subjective level of risk is always a compromise. The risks within technological production activities should always be assessed by the learners themselves.

Methods

Participants

The Techno-Risk Tolerance Questionnaire (T-RTQ) was originally tested in Finland with a nation-wide sample with 6th and 9th grade pupils from both rural and city environments as well as small and large schools (n = 393). The data consisted of a sub-sample of 9th grade technical technology pupils (n = 120) (Kallio, 2014). The sample (n = 102) of this research included 9th grade pupils from a large school in Southern Finland and from a small school in Western Finland.

Measures

The T-RTQ is a method of measuring within the Risk-Responsibility Model. Learners' conceptions of risk are presented in the model with Techno-Risk Tolerance as the dependent factor (figure 2).
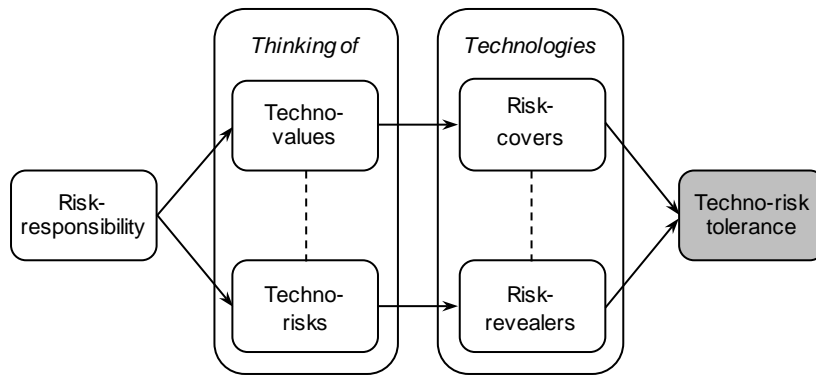
Figure 2. The Risk-Responsibility Model (Kallio, 2014).

The model was confirmed using Structural Equation Modelling. The path model fit the data (χ^2(df) = 7.61(5); RMSEA = .04; CFI = .995; TLI = .985; SRMR = .02) and the model explained 35 % of variable variation in the whole sample of learners of Technology Education (n=392). This can be considered a very high rate. The rate was up to 39 % in the sub-sample of 9th grade pupils (n = 120). (Kallio, 2014).

In the present study, the T-RTQ was re-tested and learners' conceptions were assessed with the new data of 9th grade pupils (n=102). The factors were set according to the theory of the reality network, adapted to TE (Kallio, 2014) from Bruno Latour (2003). The dimensions of the network are the learner's internal and external reality (the mind and nature) and scientific and religious or ideological believes (society and god). The dimensions were adapted to TE and cross-tabulated with technological processes, technological products, technological skills and technological resources. This produced the dimensions Succeeding & Skilfulness, Reputation & Distinction, Innovativeness & Effectiveness, Environment & Sustainability and Well-Being & Safety. While each factor consisted of three variables, the original series of measurement consisted of 123 items and the compressed version had 66 items. To limit the amount of items, the T-RTQ had nine items in total. The dimension of Safety was not included in the T-RTQ as all the other dimensions were scaled against it to determine how high risks learners were ready to take to achieve Techno-Value within each dimension.

Procedure

The assessment was done in two phases. First, the internal consistency of the T-RTQ was assessed using Confirmatory Factor Analysis (CFA) and Cronbach's (1951) Alpha was calculated. Then, the new results were compared with the previous ones (Kallio, 2014).

Table 1. The descriptive statistic of the Techno-Risk Tolerance Questionnaire (T-RTQ).

THE TECHNO-RISK TOLERANCE QUESTIONNAIRE

	M	SD	Skewness	Kurtosis	
Environment	3.41	1.14	-.42	-.36	I would not risk my safety for the environment.
Sustainability	3.24	1.18	-.25	-.65	I would not risk my safety to save natural resources or energy.
Reputation	2.79	1.17	.22	-.66	I would not risk my safety to make other learners admire me.
Distinction	2.99	1.21	-.05	-.82	I would not risk my safety to produce a product that the other learners admire.
Effectiveness	3.25	1.17	-.23	-.70	I would not risk my safety to save time.
Innovativeness	3.03	1.16	-.14	-.59	I would not risk my safety to complete a new invention.
Skilfulness	2.78	1.10	.17	-.54	I would not risk my safety to learn a new skill.
Succeeding	3.13	1.17	-.10	-.56	I would not risk my safety to finish my task.
Well-being	2.75	1.20	.19	-.68	I would not risk my safety to do something I enjoy doing.

The matrix was suitable for CFA as the skewness and kurtosis of the distribution of each variable was between -1 and +1 (Tähtinen, Laakkonen & Broberg, 2012, 74–75). CFA was used to confirm construct validity of the measurement based on the theoretical setting. In CFA, the researcher determines the factor structure. That is, identifies each variable with a factor (Hoyle, 2012; Cooper, 2006, 863). The factor structure is then used to evaluate the validity of the model (Brown & Moore, 2012; Curran, West & Finch, 1996). Determining a tolerable level of risk was based on a previously confirmed theory so in this research, CFA was used to confirm internal consistency of the model with the new sample.
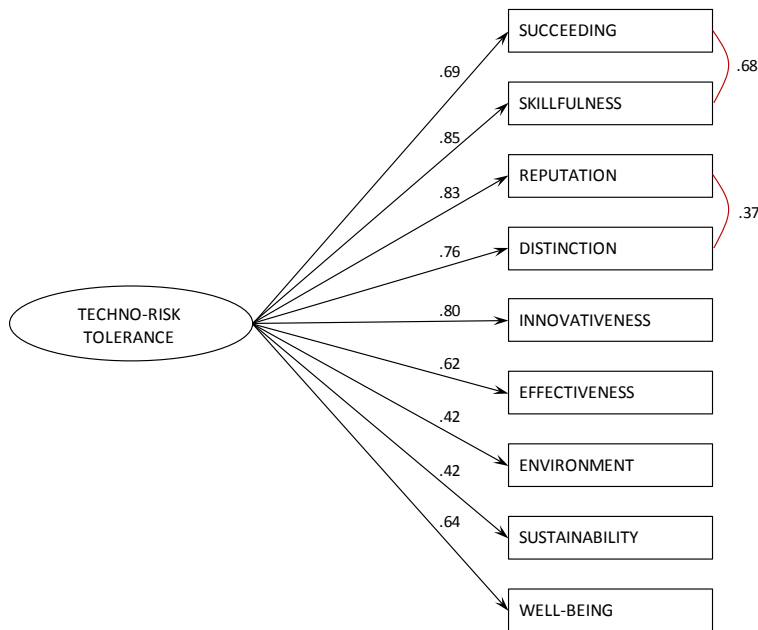
X²(df) = 41.10(25)p=.02; RMSEA = 0.08; CFI = .96; TLI = .94; SRMR = .05

MLR estimation (Mplus 6.11 Structural Equation Modelling Software)
Factor loadings are all significant (p < .001)

Figure 3. *Confirmatory Factor Analysis (CFA) of the Techno-Risk Tolerance Questionnaire (T-RTQ).*

Results

Question 1

The model fit the data well (χ^2(df) = 41.10(25); RMSEA = .08; CFI = .96; TLI = .94; SRMR = .05). The χ^2 -test revealed better fit of the factor structure than in the previous study (χ^2(df) = 53.29(25, n = 393) p = .001). However, the χ^2 -test is sensitive to sample size. The other indexes had slightly higher values than in the previous measurement (RMSEA = .05; CFI = .98, TLI = .97; SRMR = .03). The difference in sample size could explain these differences. The factor loadings weren't in line for all the factors but none of the factors could be excluded as they all measured a different dimension of Techno-Risk Tolerance. Connections between the factors were added according to theory and the results of the previous studies. The fact that some factors had lower values did not affect model fit. The factor loadings were all statistically highly significant (p < .001). Since the Cronbach's Alpha for the T-RTQ is .89 (n = 102), the measurement was found reliable. The Confirmatory Factor Analysis (CFA) confirmed that the factor structure fit the data revealing the validity of the questionnaire. The Techno-Risk Tolerance was confirmed to be measured using the T-RTQ.

Question 2

The results revealed that the T-RTQ produces consistent measurements within different samples.
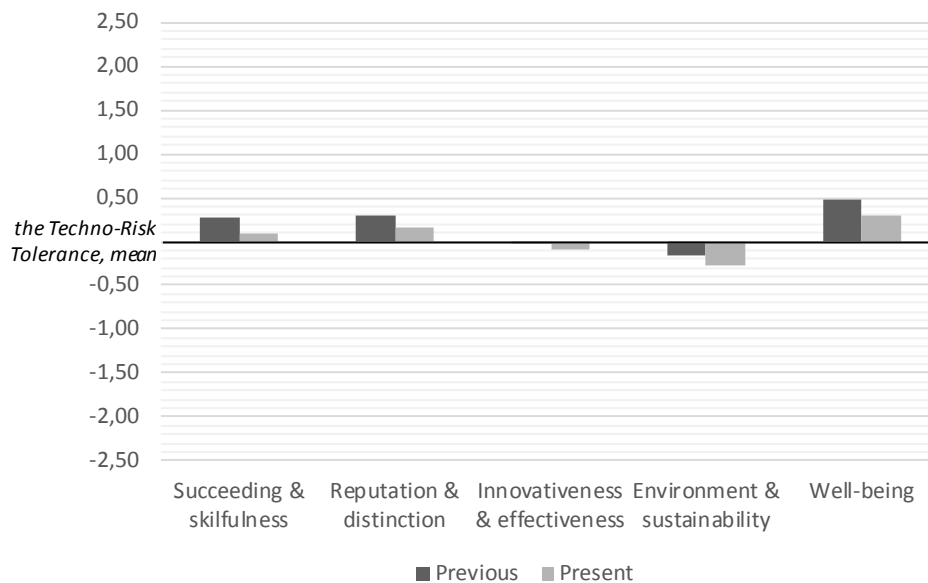
The differences in learners' conceptions on a five point scale.
Zero-level was set at the Mean of the present data (see table 1).

Figure 4. Learners' Conceptions of the Factors of Techno-Risk Tolerance.

The values for learners' conceptions of Techno-Risk Tolerance within each factor were systematically slightly higher in the new data compared with the previous study. Statistically however, the Means didn't differ (t-test, p > .05, all factors). The results were similar between the samples with each factor which shows that the T-RTQ provides consistent results. The previous study showed that the differences between the factors were more significant when measured without the learners considering the relation between the benefits of taking risk and safety (Kallio, 2014). While the learners avoided risk in some activities, they were ready to take more risk in others. The consistent new results confirm validity of the T-RTQ.

Limitations of the study

The narrow sample does not make it possible to generalize results on learners' conceptions of Techno-Risk Tolerance but the T-RTQ has been tested on a larger sample previously. The new results were consistent with the previous ones so the new results can be considered reliable. The dimensions of the T-RTQ couldn't be used as factors directly. A small number of factors is usually considered a sign of a good measure. Internal consistency of the T-RTQ was good and the new results were in line with previous ones so the results can be considered valid.

Even though the dimensions were divided into factors, the T-RTQ is limited in differentiating the dimensions of Techno-Risk Tolerance but the values varied for each dimension. Techno-Risk Tolerance was most meaningful with Skilfulness, Reputation, Innovativeness, Distinction and Succeeding. It was the least meaningful with Environment and Sustainability. The T-RTQ is better for measuring within the dimensions that had the higher values. It could be that Technology Education (TE) is not as strongly related to the dimensions with the lower values or that the learners simply didn't consider these dimensions to be related with the risks they took.

Discussion

At the end of the last century and until recent years, risks were avoided with the aim for zero risk. This led to avoiding beneficial risks as well. While Safety Education and learning environments have developed, it has been forgotten that safety is a part of well-being. Well-being can't be developed without taking productive risks. Therefore, Safety Education should educate learners to take responsibility for their own Techno-Risk Tolerance.

Techno-Risk and Techno-Value have not been taken into due consideration. This has led to a decrease in responsibility over Techno-Risk Tolerance. As well as the learners, also teachers and schools should assess the ratio. The purpose of this research was to assess learners' conceptions of Techno-Risk Tolerance. The results showed that the T-RTQ is a consistent measure and can be used for larger samples as well.

Finally, it is not purposeful to allow learners to put themselves at risk at their own responsibility. Techno-Risk Tolerance in Technology Education (TE) should be assessed together with the learners. Immediate benefits such as learning new skills or producing innovative products motivate to take risks but facing the risks can also lead to failure. Living in the modern world of technology involves processing ethical questions that technological production activities can prepare learners for. Techno-Risk can be increasingly hidden in embedded systems and networks so pupils require more education in risk awareness in their technological activities. The key ideology of the late 20th century Safety Education was achieving zero risk but Safety Education of the 21st century should be aimed to educate to prepare for uncertainty of Techno-Risk.

References

Brown, T. & Moore, M. (2012). Confirmatory Factor Analysis. In: R. Hoyle (ed.) *Handbook of Structural Equation Modeling* (pp. 361–379). The Guilford Press.

Curran, P., West, S., & Finch, J. (1996). The robustness of test statistics to non-normality and specification error in confirmatory factor analysis. *Psychological Methods 1,* 16–29.

Cronbach, L. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika 16*, 297–334.

Cooper, H. (2006). Research Questions and Research Designs. In: P. Alexander & P. Winne (eds.) *Handbook of Educational Psychology* (2nd edition, pp. 849–878). Lawrence Erlbaum Associates.

Hansson, S. (1999). A Philosophical Perspective on Risk. *Ambio, Royal Swedish Academy of Science, 28* (6)*,* 539–542.

Hansson, S. (2005). The Epistemology of Technological Risk. *Techné: Research in Philosophy and Technology, 9* (2).

Hollander, R. (1997). Social Construction on Safety. In: K. Shrader-Frechette & L. Westra (eds.) 1997. *Technology and Values* (pp. 107–114). Rowman & Littlefield Publishers.

Hoyle, R. (2012). Model Specification in Structural Equation Modeling. In: R. Hoyle (ed.) *Handbook of Structural Equation Modeling* (pp. 127–144). The Guilford Press.

Kallio, M. (2014). *Risk-Responsibility in Safety Education Culture*. Annales Universitatis Turkuensis C: 382.

Latour, B. (2003) Do You Believe in Reality? New Trenches of the Science Wars. In: R. Scharff & V. Dusek (eds.) *Philosophy of Technology. The Technological Condition. An Anthology* (pp. 126–137). Blackwell Publishing.

Reason, J. (2008). *The Human Contribution. Unsafe Acts, Accidents and Heroic Recoveries.* Ashgate Publishing.

Shrader-Frechette, K. (1992). Technology. In: L. Becker & C. Becker (eds.) *Encyclopedia of Ethics* (2nd edition, pp. 1231–1234). New York: Garland Publishing

Shrader-Frechette, K. (2003). Technology and Ethics. In: R. Scharff & V. Dusek (eds.) *Philosophy of Technology. The Technological Condition. An Anthology* (pp. 187–190). Blackwell Publishing.

Tähtinen, J., Laakkonen, E. & Broberg, M. (2012) *Tilastollisen aineiston käsittelyn ja tulkinnan perusteita [An Introduction to Statistical Data Processing and Interpretation].* Turun yliopiston kasvatustieteiden tiedekunnan julkaisuja C: 20 [University of Turku Publications, Faculty of Education].

Design and Technology Education as learning agency: and the fourfold of 'critiquing skills'

Steve Keirl
Goldsmiths, University of London, Department of Design
UK
s.keirl@gold.ac.uk

Abstract

This paper offers a brief exploration of conceptual issues around 'skills' and its derivatives. It offers some theoretical background and it invites consideration of Design and Technology as a 'learning agency'. The core argument is that *critiquing skills* are necessary skills for the field and that the term 'critiquing skills' can be considered in four ways. There is much to be researched around the genre of skills in Design and Technology and the paper also suggests four curriculum considerations: the politics of skilling; the ontologies of skilling; the temporalities of skilling; and, education of, for, and through skilling. The aim of the paper is to help see the notion of 'skills for the 21st Century' as problematic for education.

Key words   Skills, critiquing, curriculum, knowledge, ontology, technological literacy

Orientations

After the toddling-age we walk on pavements without minding our steps. But a mountaineer walking over ice-covered rocks in a high wind in the dark does not move (his) limbs by blind habit; he thinks what he is doing, he is ready for emergencies, he economises in effort, he makes tests and experiments; in short he walks with some degree of skill and judgement. If he makes a mistake he is inclined not to repeat it, and if he finds a new trick effective he is inclined to use it and to improve on it. He is concomitantly walking and teaching himself how to walk in conditions of this sort. It is of the essence of merely habitual practices that one performance is a replica of its predecessors. It is of the essence of intelligent practices that one performance is modified by its predecessors. *The agent is still learning*.' (Ryle, 1949/1973:42. My italics)

Skill is intensive and refined world engagement. Skill, in turn, is bound up with social engagement. It molds the person and gives the person character. *(He cites Sturt's excellent 1923 chronicle: The Wheelwright's Shop)* (Borgmann, 1984/2004:116. Comment added.)

Throughout history, at least in the Western world, the project of technology has been to capture the skills of the craftsman or artisan, and to reconfigure their practice as the application of rational principles the specification of which has no regard for human experience and sensibility. (Ingold, 2006:78)

Skills – sketching the background

If ever there was a term to excite epistemological discussion it could be 'skill'. Skill resists fine definition or being positioned in any particular knowledge camp. When Ryle

(1949/1973:17) set about challenging '…with deliberate abusiveness…' what he called "the Ghost in the Machine" (Decartes' hugely influential separation of 'mind' and 'body') he contributed helpfully to Design and Technology's (D&T's) own deliberations. This paper offers a brief exploration of conceptual issues around 'skill-skills-skilling'; examines some associated contextual considerations; invites consideration of D&T as a 'learning agency'; and; suggests that *critiquing skills* are necessary skills for the field and that they might be considered in four ways.

Ryle distinguished between 'knowing that' (sometimes: propositional or declarative knowledge of the 'fact'-type) and 'knowing how' (procedural knowledge). Mitcham (1994) explores the idea of technology-as-knowledge and offers a spectrum of distinctions. The 'least conceptual' of these is sensorimotor skill. For him, such skills '…of making and using are preconscious "knowhow" more than "know that", acquired by intuitive as well as trial and error learning or imitative apprenticeship…and thus do not qualify as knowledge in the strict sense.' (Mitcham, 1994:193). However, he also reports how phenomenologists such as Dreyfus (below) see skills as cognitive development and that, in the domain of skill: '…there is no transformation, even at the level of expertise, to abstract or formal and therefore conceptually teachable knowledge.' (Mitcham, 1994:196).

The nature of skill-knowledge is differently articulated by Polanyi's (1958/1974; 1966/2009) work on tacit knowledge – that which we have but which we can neither show nor accurately describe. This includes '…the performance of skills, whether artistic, athletic, or technical. We have here examples of knowing, both of a more intellectual and more practical kind; both the "wissen" and "können" of the Germans, or the "knowing what" (sic) and the "knowing how" of Gilbert Ryle. These two aspects of knowing have a similar structure and neither is ever present without the other.' (Polanyi, 1966/2009:6-7). Polanyi (1958/1974:54) has also differentiated between skill (as the art of doing) and connoisseurship (as the art of knowing) – both of which, he contends, are transmissible.

Collins & Evans (2007/2009) expand a tacit knowledge thesis and present their 'periodic table of expertises'. They describe what they call 'ubiquitous expertises', that is: '…all the endlessly indescribable skills it takes to live in a human society; these were once thought of as trivial accomplishments.' (Collins & Evans. 2007/2009:16)   This distinction is helpful when considering the multiplicity of skills development expected of education.

Ryle argued skills to be 'acquired dispositions' or intelligent capacities and he distinguishes them from habits. Someone doing something by blind habit does so '…automatically and without having in mind what he (sic) is doing. He does not exercise care, vigilance, or criticism'. (Ryle, 1949/1973:41). More recently, Sennett (2008) offers a general understanding that 'skill is a trained practice' – which he contrasts with sudden inspiration. He notes that as skills develop, the *content of what is practised changes*. This fits with the notion of skills as tacit knowledge as that which is tacit grows and, in several senses, develops. It is not simply a fixed form of knowledge to be taken on board by the learner. Sennett further points to the role of skill development happening as more, and increasingly difficult, problem situations are encountered. 'The open relation between problem solving and problem finding, as in Linux work, builds and expands skills, but this can't be a one-off event. Skill opens up in this way only because the rhythm of solving and opening occurs again and again.' Sennett (2008:38)

Ingold (1993/1994b) distinguishes amongst technology, technics and technique and the last of these refer to '…skills, regarded as the embodied capabilities of particular human subjects…' and he reminds us (citing Mauss) that '…it is a fundamental mistake to think that "there is technique only where there is an instrument"'. (Ingold, 1993/1994b:433). Meanwhile Mitcham (1994:197) reports Bunge's distinction between technical practice (engineering, medicine, etc) and technics (artisanal craft skills).

As with most scholars, Ingold resists the idea that skill might be considered the *application* of knowledge because '…acting in the world is the skilled practitioner's way of knowing it. The perceptual knowledge so gained is…an integral part of personal identity. Hence, in the constitution of their environments, agents reciprocally constitute themselves as persons.' (Ingold, 1993/1994b:443) It is in such statements that the important ontological dimension of skills and skilling begins to present itself. The work of Dreyfus on Heidegger is very helpful here.

As Dreyfus reports, Heidegger moved away from an epistemological approach to argue an ontological one. No matter one's take on how we think we 'know' this or that about the world, Heidegger brings matters down to the ontological, that how we make sense of things amounts to how we *are* in the world. 'Thus Heidegger breaks with Husserl and the Cartesian tradition by substituting for *epistemological* questions concerning the relation of the knower and the known, *ontological* questions concerning what sorts of beings we are and how our being is bound up with the intelligibility of the world.' (Dreyfus, 1991:3) Heidegger, Dreyfus reports, seeks to reverse Decartes conclusion from "I think therefore I am" to "I am therefore I think".

For D&T education, Heidegger has led the way on showing how our very being is technological – whether through the skilful use of technologies; our adoption of them; our intimate relations with them; or for how they shape our futures. Importantly, he has said that '…the essence of technology is by no means anything technological' (Heidegger, 1954/1977:4) reminding us that neat dictionary definitions or common stereotypes about the nature of technology are simply inadequate for our proper understanding of the phenomenon. Existential discourse offers invaluable critique of how we understand 'skill'. Consider, for example, this statement: '…our understanding of our being is never fully accessible since (1) it is embodied in skills and (2) we dwell in our understanding like fish in water.' (Dreyfus, 1991:35)

Dreyfus reports that Polanyi, Kuhn and Heidegger alike consider inadequate the view held for 2500 years that there exists 'theoretical, disinterested knowledge'. They argue that such knowledge actually '…presupposes a practical and involved "know-how" that cannot be accounted for in terms of theoretical knowledge. According to these thinkers, theoretical knowledge depends on practical skills.' (Dreyfus, 1991:46)

Dreyfus also discusses the inconclusive discourse around Leibniz's view that skills amount to theories we are not yet clear about. (D&T can be well articulated via the playfully ambiguous 'knowledge-in-the-making'.) To this end he cites, first, Habermas's claim that in goal-directed actions such as skills '…an implicit knowledge is expressed; this know-how can in principle also be transformed into a know-that' and then, Papert's claim that '…even physical skills such as bike-riding and juggling are performed by following theories.' (Dreyfus, 1991:86). Such cognitivist positions are countered, Dreyfus argues, by Heidegger's claim that '…when we carefully describe everyday ongoing coping activity we do not find any mental states'. That is, in our everyday lives we operate skilfully and

without conscious acknowledgment of any operational theory or thought process. This has its parallel in the learning of a skill when it might be said that someone is skilful when they no longer have to think about what they are doing. 'The novice becomes skilled not through the acquisition of rules and representations, but at the point where he or she is able to dispense with them.' (Ingold, 1993/1994a:462) Thus we consider the reflective feedback engaged when skilful practice encounters new challenges for which the skill is suited but which is in need of considered application (the thoughtful mountaineer's footwork perhaps). Schön's (1983) work on 'reflection-in-action' resonates here too.

The genre of skills

Having some understanding of the theoretical underpinnings of 'skill' and its derivative terms is essential but their application demands perspective too. Habermas (1971) offers a practical philosophy informed by critical theory that invites us to be mindful of whose, and what kind of, *knowledge interests* are being served when we consider what it means to be skilled (or otherwise). In outline, he proposes we consider: i) the *technical* where knowledge remains at the instrumental or functional level; ii) the *practical-hermeneutic* that facilitates capacities to operate in and understand the world; and iii) the *critical-emancipatory* that facilitates personal autonomy, fulfilment and critical-participatory being-in-the-world.

A ready starting point is the 'skills agenda' so evident in current political-economic ideology (for it is more than just policy) in many countries. A major question for the politics of education is whether education be led by the needs of industry and business. Claims that students should be 'work-ready' or need to be trained (sic) to meet skills shortages are all indicators of a particular politics of education. A different politics might, for example, privilege education over training; the democratic and social good over industry and business; or, the environment over 'the market'.

Helpfully, one methodology of the Habermasian approach is *ideology critique* which seeks to interrogate the values, beliefs and practices of particular dominant groups. A prime candidate is the current neo-liberal economic ideology of aggressive capitalism while simultaneously demanding skills-as-needed and multiple forms of de-skilling: de-skilling ourselves by accepting 'automated' and 'smart' technologies into our lives; deskilling or displacing craftspeople; deskilling professions such as teachers by dictating curricula, assessments and pedagogies; and, deskilling participatory citizenship both by stifling debate and dissent, and by leaving technological decision-making to elites of experts (Sclove, 1995; Feenberg, 2010).

We might accept that it is useful to several parties to 'be skilled' but when we consider de-skilling, re-skilling, up-skilling; being unskilled; soft skills; hard skills; and more, it might be worth asking whose interests are being served. Further, there is the ill-distribution of skills or the control of the associated knowledge and practices whether historically by guilds, by apprenticeship models, by labour and market control mechanisms, or by discrimination. The more one looks the clearer it becomes that 'skill' can be a multifaceted and multi-located concept. We might further consider:

Gender politics and skills… 'How has it come about that women have failed to achieve recognition of the skills required by their work? …Definitions of skill can have more to do with ideological and social constructions than with technical competencies...' (Wajcman, 1991:37; see also Haraway, 1991; Cockburn, 1999; Wajcman, 2004)

Levels of skilling, and for who's good…? One's capacities and power are informed by skill levels. 'Limitations of skill confine any one person's primary engagement with the world to a small area' Borgmann (1984/2004:116). As with any form of education, if people's skilling is limited then individuals and society alike are the poorer as a result. Sennett writes of 'antisocial expertise' as '…an inherent inequality of knowledge between expert and nonexpert' as opposed to 'sociable expertise' which serves the common good (Sennett, 2008:248-249). Sennett (2008:52) also articulates a common concern around skill marginalisation by new technologies. 'When the head and the hand are separated, the result is mental impairment – an outcome particularly evident when a technology like CAD is used to efface the learning that occurs through drawing by hand.' (For a parallel D&T discussion, see McLaren, 2008)

Skill-suppression by association…   Greenhalgh (1997) shows how, over the twentieth Century, 'craft' (and associated skills) has been positioned negatively against 'progress' and 'industrial culture'. 'To a considerable extent, craft has been seen as the cultural Luddism of our times… Consequently, in an age of mass communications and technology-driven positivism, it has been portrayed as a reactionary force and accordingly marginalised.' (Greenhalgh, 1997:104)

Skills as personal re-invention… Ingold (2006) discusses the *fate of skill* and points to the ever-reinvention of skills – that as soon as humans endeavour to adapt skills and techniques into machines and computers, people have a fascinating habit of developing new skills with the new devices: '…the essence of skill has come to lie in the improvisational ability of practitioners to disassemble the constructions of technology, and creatively to incorporate the pieces into their own walks of life.' (Ingold, 2006:79)

This brief section has given a flavour of the complexity and richness of what might be called *the genre of skills*. I'd argue that the term 'skill' and its derivatives are too lightly, and uncritically, used within, or about, our field. The term is problematic and should be treated problematically by educators. There is much to be research around the genre of skills and D&T and this investigation suggests four D&T curriculum considerations: the politics of skilling; the ontologies of skilling; the temporalities of skilling; and, education of, for, and through skilling.

Design and Technology as learning agency
The title of this paper was inspired by Ryle's (1949/1973) distinction between 'habitual practices' (agent as replicator) and 'intelligent practices' (agent as learner). I suggest that D&T could be considered as a learning agency, that is, as a *site of intelligent practices*, as a site for *knowledge-in-the-making*. Such an agency might be informed by the following notional criteria (noting that these are addressed to general education – the years of compulsory schooling for *all* children):

Contributing to an education where:
- all the 'agents': teachers, administrators, and pupils alike, are co-learners (Boomer, 1989/1999);
- the educational fulfilment of children is privileged over materialist outcomes;
- democratic and sustainable futures are privileged over unsustainable socially and environmentally harmful economic ends (Keirl, 2015a);
- critical-constructivist pedagogies are the norm; and,

- initiation (Peters, 1966), training, enculturation and indoctrination are each understood for what they are.

Within the above, D&T as learning agency:
- works to advance ethical-critical technological and design literacies (Keirl, 2015b);
- is celebrated as a 'doing' field, design-rich, critical in nature, and ethically-focussed;
- is resistant to, and critical of, divisions of the academic-vocational kind and is actively resistant to gendered and class-based division;
- practises rich and critical design-oriented pedagogies rather than those of narrow instrumentalism (Freire 1972, Keirl, 2016);
- is resistant to prescriptive content-dependent curriculum and celebrates the interplay of *knowing how* and *knowing that* through critical-constructivist pedagogy;
- initiates learners into a multiplicity of skills rather than an educationally restrictive few; and,
- uses assessment as a personal learning support for each agent and not as an instrument of classification.

Within the above, skilling:
- is understood richly as a combined ontological, epistemological and social good. 'The practice of skills is inventive; by concentrating our purpose on the achievement of success we evoke ever new capacities in ourselves.' (Polanyi, 1962/1974:128);
- is much more than learning 'how to'. Ingold (1993/1994a:462) cites Lave's (1990) distinction between 'understanding in practice' and 'the culture of acquisition'. He also distinguishes between 'enculturation' (into that which already exists) and '...*enskillment*, in which learning is inseparable from doing, and in which both are embedded in the context of practical engagement in the world – that is, in dwelling.' (Ingold, 1993/1994a:463);
- advances all three Habermasian *knowledge interests*: and,
- develops 'intelligent capacities' which '...involves the stimulation by criticism and example of the pupil's own judgement.' (Ryle, 1949/1973:42)

The fourfold of 'critiquing skills'
It is argued that talk of 'skills for the 21ˢᵗ Century' warrants interrogation. Thus, it is also argued that 'D&T as learning agency', along with the associated notional criteria set out above, calls for practices of criticism, critique, critical thinking, critical reflection (Schön, 1983), and more. (On the emergence of these in D&T, see Williams & Stables, 2016). Thus, the phrase *critiquing skills* might have four senses:
1. *skills of critiquing* at the meta or philosophical level. Here, critical thinking and critical discourse are practised as philosophical method. Skills of critiquing serve to interrogate philosophical arguments, positions and claims;
2. (applying 1, above) *critiquing 'skills'*, that is, interrogating critically the very concept of 'skill' and its derivatives. Questioning meanings, purposes, interests, benefits, and limitations;
3. *skills of critiquing* in the micro and meso levels of practices of D&T learning. Here, critiquing plays multiple roles in enhancing technological and design literacies (Keirl, 2016); and,
4. *skills of critiquing* as a component of general education serving all learning agents to the benefit of a common good. Here, the practice of critiquing serves the wellbeing of democracy by enhancing discourses and debate while challenging passivity and blind acceptance of unworthy ways of being-in-the-world.

'Skill' and its derivatives are commonly linked to our field but responsible Design and Technology education must consider, in many ways, for all its learners, a suite of critically 'intelligent practices' for its own skilful being-in-the-world.

References

Boomer, G., (1989/1999), 'Education and the Media – Makers or Mirrors? Dilemmas in the development of Australian culture' in (Ed.) Green, B., (1999), *Designs on Learning: Essays on curriculum and teaching by Garth Boomer,* pp. 71-81, Australian Curriculum Studies Association, Canberra.

Borgmann, A., (1984/2004), 'Focal Things and Practices,' in Kaplan, D. M., (Ed.), (2004), *Readings in the Philosophy of Technology*, pp115-136, Rowman and Littlefield, Lanham.

Cockburn, C., (1999), 'The material of male power' in (Eds.), MacKenzie, D. & Wajcman, J., (1999), *The Social Shaping of Technology*, 2nd Edition, pp 177-198, Open University Press, Buckingham.

Collins, H. & Evans, R., (2007/2009), *Rethinking Expertise*, University of Chicago Press, Chicago

Dreyfus, H.L., (1991), *Being-in-the-World A Commentary on Heidegger's Being and Time – Division 1,* The MIT Press, Cambridge, Massachusetts.

Feenberg, A., (2010), *Between Reason and Experience and Experience: Essays in Modernity and Technology,* MIT Press, Cambridge, MA.

Freire, P., (1972), *Pedagogy of the Oppressed*, Penguin, London

Greenhalgh, P., (1997) 'The Progress of Captain Ludd' in Dormer, P., (Ed.), (1997), *The Culture of Craft: Status and future*, pp. 104-115, Manchester University Press, Manchester.

Habermas, J., (1971), *Knowledge and Human Interests*, Beacon, Boston.

Haraway, D., (1991) 'A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century,' in *Simians, Cyborgs and Women: The Reinvention of Nature*, (1991, pp149-181), New York, Routledge.

Heidegger, M., (1954/1977), *The Question Concerning Technology and Other Essays,* (trans. Lovitt, W.), Harper & Row, N.Y.

Ingold, T., (1993/1994a), 'Technology, language, intelligence: A reconsideration of basic concepts' in Gibson, K. R. & Ingold, T., (Eds.), (1993/1994), *Tools, Language, and Cognition in Human Evolution*, pp. 449-472, Cambridge University Press, Cambridge.

Ingold, T., (1993/1994b), 'Tool use, sociality and intelligence' in Gibson, K. R. & Ingold, T., (Eds.), (1993/1994), *Tools, Language, and Cognition in Human Evolution*, pp. 429-445, Cambridge University Press, Cambridge.

Ingold, T., (2006), 'Walking the Plank: Meditations on a process of skill' in (Ed.) Dakers, J.R., (2006), *Defining Technological Literacy: Towards an epistemological framework*, pp. 65-80, Palgrave Macmillan, Basingstoke.

Keirl, S., (2015a), 'Against Neoliberalism; For Sustainable-Democratic curriculum; Through Design and Technology Education', in Stables, K. & Keirl, S., (Eds.), (2015), *Environment, Ethics and Cultures: Design and Technology Education's Contribution to Sustainable Global Futures,* pp, 153-174, Sense, Rotterdam.

Keirl, S., (2015b), 'Global ethics, sustainability, and Design and Technology Education', in Stables, K. & Keirl, S., (Eds.), (2015), *Environment, Ethics and Cultures: Design and Technology Education's Contribution to Sustainable Global Futures,* pp. 33-52, Sense, Rotterdam.

Keirl, S., (2016 Forthcoming), 'Critiquing as Design and Technology curriculum journey: history, theory, politics, and potential' in Williams, J. & Stables, K., (Eds.), (2016 Forthcoming), *Critique in Technology Education,* Springer, Dordrecht

McLaren, S., (2008), 'Exploring perceptions and attitudes towards teaching and learning manual technical drawing in a digital age', *International Journal of Technology and Design Education*. 18:2:167-188

Mitcham, C., (1994), *Thinking Through Technology: The Path between Engineering and Philosophy*, University of Chicago Press, Chicago.

Peters, R.S., (1966), *Ethics and Education*, George Allen & Unwin, London

Polanyi, M., (1958/1974), *Personal Knowledge: Towards a post-critical philosophy*, University of Chicago Press, Chicago.

Polanyi, M., (1966/2009), *The Tacit Dimension*, University of Chicago Press, Chicago.

Ryle, G., (1949/1973), *The Concept of Mind*, Penguin, Harmondsworth.

Schön, D. A., (1983) *The Reflective Practitioner: How professionals think in action*, Jossey-Bass, San Francisco, CA.

Sclove, R.E., (1995), *Democracy and Technology*, The Guilford Press, N.Y.

Sennett, R., (2008), *The Craftsman,* Yale University Press, New Haven.

Sturt, G., (1923/1993), *The Wheelwright's Shop*, Cambridge University Press, Cambridge.

Wajcman, J., (1991), *Feminism Confronts Technology*, Polity Press, Cambridge.

Wajcman, J., (2004), *TechnoFeminism*, Polity Press, Cambridge.

Williams, J. & Stables, K., (Eds.), (2016 Forthcoming), *Critique in Technology Education,* Springer, Dordrecht

Critical aspects of welding: negotiating an object of learning in vocational school

Kilbrink Nina
Karlstad University, Department of Educational Studies
Sweden
nina.kilbrink@kau.se

Asplund Stig-Börje
Karlstad University, Department of Educational Studies
Sweden
stig-borje.asplund@kau.se

Abstract

The learning process in programme-specific subjects in technical vocational education often involves treating the object of learning in student-teacher interaction. Teaching also often includes handling different tools and materials manually. In this paper, we discuss the process of learning a specific object, namely learning to weld as it emerges in interaction between a teacher and a student in a teaching situation in a technical vocational classroom. The focus is on both the what-aspect and the how-aspect of learning, where variation theory is the analytical framework for the what-aspect of learning, and conversation analysis (CA) is the analytical framework for the how-aspect. By intertwining the two methods/frameworks we can get a deeper understanding of the learning process concerning a specific object of learning.

Keywords: Vocational learning; Variation theory; Conversation analysis, Learning content, Technical vocational education.

Introduction

Teaching and learning in vocational subject areas as well as learning a technical content have been highlighted as specific in different studies and handicraft, practical experience and physical work emphasized as central parts (cf. Bjurulf, 2008; Kilbrink, 2013). Furthermore, Björkholm (2015) argues for the importance of studying technical objects of learning in order to learn more about teaching and learning technology. The object of learning (OoL) in programme specific subjects in technical vocational education is often handled in interaction between student and teacher. However, there are few studies focusing on how those learning objects are being taught and learned in the interaction between student and teacher. In this study we focus on the OoL *to weld* and more specifically on what is possible to learn about welding in the learning interaction and how the learning content is made relevant in the interaction.

Previous studies using the variation theory have focused on the content in teaching and learning, without focusing on the interaction between the teacher and learner (cf. Bjurulf, 2008). However, the social interaction can influence how the content is highlighted in the learning situation, and by studying how the OoL is manifested during the interaction, we can get a deeper understanding on learning processes concerning both *what* is being learned and *how this learning is done* in interaction. This can be done by integrating a variation theory analysis (VTA) with a conversation analysis (CA) of the

interaction on a specific OoL in a teaching situation (Asplund & Kilbrink, 2016). By combining the two perspectives VTA and CA, we aim to reach a broader knowledge about both the what- and the how-aspects of learning a specific OoL in technical vocational education. The research question for this study is:

Which critical aspects of the OoL to weld are oriented to and how are they made relevant in the interaction between a student and a teacher in a learning situation?

Theory and Method

This study is based on the view that learning is a process, comprising the aspect of *what* is being learned and *how* learning is done in interaction in the actual teaching situation (Emanuelsson & Sahlström, 2008, Marton & Tsui, 2004; Sahlström, 2011). In variation theory, there is an emphasis on the learning content as the OoL. The OoL can differ between what the teacher planned for (the intended OoL), what was possible to learn in the teaching/learning situation (the enacted OoL) and what the students learned (the lived OoL) (Marton & Tsui, 2004). In this study, we focus solely on the enacted OoL and what was possible to learn in the interaction between a vocational student and his teacher. Critical aspects are the aspects that are important to understand in order to learn an OoL. Which critical aspects to focus on in teaching can differ between different students (ibid.). The critical aspects can be highlighted in teaching by using different patterns of variation. In variation theory there are four patterns of variation – *fusion*, which means that all critical aspects are present at the same time; *separation*, which means that one critical aspect of the OoL is highlighted and varied, while others are kept invariant; *contrast* means that the varied critical aspect is compared to something it is not; and finally, *generalization* means that the critical aspect is highlighted by showing different appearances of the critical aspect (ibid.). The critical aspects of the OoL that emerge in the interaction and the patterns of variation that are used in relation to those emerged critical aspects are focused on in the VTA.

CA focuses on how meaning and understanding are established, sustained and changed in and through the coordinated interaction of people and the interaction between people and artefacts in specific social and cultural contexts (Sahlström, 2009). In CA, language and body are seen as tools through which people construct and reconstruct their social reality, and a central principle in CA is that it takes a radical participant perspective. What is to be studied is how conversation participants produce an action and how they show their interpretation and understanding of other participants' actions and of the new actions generated (Schegloff, 2007). Thus, in this paper, not only talk but also other semiotic resources such as bodies, gazes and physical objects are seen as constitutive of the activity being analysed. In this work, and in line with the CA approach, we will use detailed transcriptions of spoken data as well as visual phenomena in the interaction between the teacher and the student.

Analysis and Results

Two sections from a film where a vocational teacher and a student interact in relation to learning to weld were chosen and have been analysed in detail using VTA and CA. The critical aspects emerging in the interaction will be highlighted in **bold** text, and the pattern of variation used in relation to the critical aspects will be shown in *italics*. How those critical aspects and patterns of variation are oriented to in the interaction will be shown in the CA analysis, interwoven in the VTA analysis.

Example one

The video recorded film starts when the teacher (T), seated on a bench, starts to weld on a small weld metal, while the student (S) stands to the left watching:

In the recorded scene there is work in process in which the teacher positions himself as the more knowledgeable other and thus gains epistemic authority (Vähviläinen, 2009) while the student takes the role of being the less skilled of the two. This is a relationship that is established as soon as the teacher takes the position as the expert, sits down and shows the student how the welding should be done.

When the teacher then takes the role of the expert and shows the student how to weld, his welding becomes a model of how the welding process should proceed, and from a VTA perspective there are several critical aspects of the learning object to weld present simultaneously. The variation pattern that is made visible in this situation is *fusion* and the student sees the teacher as a role model who demonstrates the actions that the student himself is expected to do.

When the teacher has finished his welding, a sequence follows where he verbalises to the student what to think about when welding as follows:

1. T: If this is (.) if this is the welding nozzle ((Bends the top of the welding wire in a
2.   45 degree angle.))
3. S: Yea:h.

T: Then you have about the same. (.) First you should have ninety degrees like .

4.   this.

In this example, the critical aspect of welding highlighted in the teaching situation is the **angle** of the welding nozzle. This is the focus in the interaction between the student and the teacher. The example begins with the teacher "transforming" (line 1) the welding wire that he is holding in his hand into a welding nozzle by saying "if this is the welding nozzle" while bending the upper part of the welding wire in a 45 degree angle, and simultaneously using different kinds of semiotic resources (talk, embodied actions and artefact) in order to demonstrate the process of the transformation of the welding wire. The welding wire, from this point on, is thus the basis and starting point for the continued instruction of how to weld, i.e. the teacher and the student continue to relate to the welding wire as a welding nozzle. In this way, the **angle** at which the welding nozzle is supposed to be held is *separated* from all other critical aspects. By using

generalisation the teacher illustrates how the angle should be – both with the real nozzle, and with the wire that he bends like the welding nozzle in order to show the right the angle to the student.

Example 2:

In the second example, Robin has been welding on his own in front of the teacher for a short time and then Robin is encouraged by his teacher to "get some rest":

1. T: Now it will be hot. You can take some rest. (.) Do you know what is strange,
2.   Robin!?
3. S: No?
4. T: When you have: (.) Hmm. (.) When you have the weld too high -
5. S: Yes:?
6. T: Then it gets too hot.
7. S: Yes. ((Lifts the plate and looks at it.))
8. T: And when you push the weld down (.) then it gets cooler.
9. S: Yes?
10. T: You have to fool the brain a little.
11. S: Oka:y.
12. T: Because you know ((looks at Robins face)) when it gets hot then
13.   you want to pull away, don't you?
14. S: Yes.
15. T: But when you pull away then it gets even hotter.
16. S: Okay.
17. T: Try again, we'll see.
18.   ((Robin starts to weld again.))

19. T: Angle more Robin. Yes, so. (.)
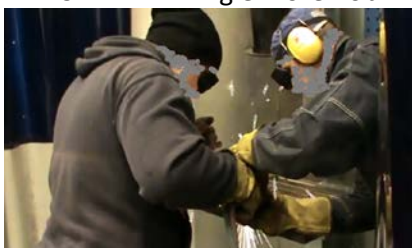
20.   ((Grabs Robin's right hand which is holding the weld. Moves the hand down
21.   towards the bench at angel from Robin's body.)) Aim like tha:t (.) Tha:t's
      right

When Robin has welded for a while, the teacher makes Robin aware that "it" will be hot and that he should rest for a while from the welding process (line 1). In this sequence, **heat** emerges as a critical aspect of welding in the interaction, by being singled out from other critical aspects using *separation* as pattern of variation. The teacher follows up his request with a rhetorical question ("Do you know what is strange, Robin?") which leads to a situation in which the teacher again is given the epistemic authority – he is positioning himself as the more knowledgeable (teacher) who can show his skills by

instructing the student how to weld. But in this section he is not doing it as a role model, where all critical aspects are shown by fusion, but by emphazising different critical aspects one by one, using *separation*. In the turns that follow, it is the welding nozzle's distance to the goods being welded that the teacher and the student orient towards, and, according to the teacher's action, it is also made clear that the distance to the plate that they orient to, follows a "different" logic and therefore also demands a "different" way of thinking.

In lines 4 and 6 the teacher informs the student that if he holds the welding nozzle "too high" during the act of welding, it then "gets too hot". Here the **heat** is highlighted as a critical aspect by *separation.* This critical aspect is emphasized as a consequence of the **distance of the welding flame to the plate**, which also emerges as a critical aspect. If he would then "push the weld down (.) it gets cooler" (line 8). The teacher then follows up this statement in line 10 with the suggestion that "You have to fool the brain a little". Hence, the values that the critical aspect **distance to the plate** can gain are: too high, to low and something in-between that is correct, but it is not explicitly made clear what it is. The pattern of variation that appears in relation to the distance to the plate could be seen as *contrasting* an expected experience that the teacher highlights in line 1 ("Do you know what is strange?"), in line 10 ("You have to fool the brain a little") and in line 12-13 ("when it gets hot, you want to pull away, don't you?"). Hence, the contrast is not made to something that is happening in the actual situation, but to something that the teacher expects the student to experience. Thus, this pattern of variation requires that the student is simultaneously aware of what happens here and now, and something that the teacher expects him to already know.

Robin's reaction in line 11 (a somewhat cautious "oka:y") is an expression of displayed attention but also a readiness to listen further. Robin's somewhat cautious response is followed up by the teacher who continues his efforts to explain how to think when one is welding. He begins this in lines 12-13, where he is positioning Robin as someone who "knows" that when "it gets hot, you want to pull away". Hence, what the teacher is doing in the example is to start from what one could say is a completely normal and natural reaction; if you are confronted with a situation where something gets too hot, the normal reaction would be to retract from the heat you are exposed to. In this specific situation, which the teacher and the student are oriented to, this means that if/when the temperature gets too hot at the welding point during the welding act, the normal/natural reaction is to remove the welding nozzle and its flame from the goods. The teacher makes the student aware that both he *and* the student already "know" this. Also, the teacher uses the expression "don't you" when saying that "when it gets hot, you want to pull away, don't you?", which is our translation of the Swedish epistemic adverb "ju" and it underlines that what is being said is something known by the other present participants (Aijmer, 1996, p. 421). Thus, the teacher's utterance is affirmed by Robin in the following turn. Then, the teacher shifts his reasoning when saying, "But when you pull away then it gets even hotter". Robin affirms this with a more distinguished "okay" than he did before (line 16) and in connection with this, the teacher asks him to "try again" (line 17). The teacher's expression "try again, then we'll see" encourages the student to continue welding. In the act of welding, the previously *separated* critical aspects are now included at the same time by the variation pattern *fusion*.
  Soon the teacher tells the student to "angle more", and the **angle** emerges as a critical aspect. In relation to this recommendation, the teacher grabs the student's arm and moves it into another position than the student has chosen himself, which could be interpreted as if verbal instructions were not enough. Thereby, the teacher uses *contrast*

as a pattern of variation, when he compares to how it should be done the actual act (both verbally by saying "angle more" and physically, by helping the student find the right value of the angle with his hands). As soon as the teacher has done this he asks the student to "Aim like tha:t" , and when the teacher says "that's right", he seems to be satisfied with the result, and the critical aspect **angle** has been ascribed its right value.

Discussion and conclusion

In the example the teacher starts by showing the whole process of welding as a role model. Then all the critical aspects are fused in the teacher's welding action. Thereafter the critical aspects are highlighted one by one in the teaching situation, when the student tries to weld under supervision. When separating the critical aspects, the teacher mostly uses contrast to highlight how something should be done, in relation to how it should not be done. The critical aspects that emerge in the interaction and how the actors orient to them can be seen in Table 1:

Table 10 Critical aspects of welding

Critical aspect	Pattern of variation	How it is done in interaction
Angle of the tool	*Generalization* (different tools to show the angle)	Different kinds of semiotic resources (talk, embodied actions and artefact) mutually contextualizing one another
Heat	*contrasting* what happens in the teaching situation to expected knowledge	epistemic authority (teacher), when showing his welding skills
Distance to the plate	*contrasting* to an expected reaction	epistemic authority (teacher), when instructing the student how to weld. The use of the utterance "don't you" and its function
Angle of the hand	*contrasting* to the actual act, both verbally and physically	Different kinds of semiotic resources (talk, embodied actions and artefact) mutually contextualizing one another

The critical aspects in relation to welding that emerge in the teaching situation (the enacted OoL) are negotiated in interaction between the teacher and the student and depending on the student's actions and handling of the tools and material involved in the process of learning to weld.

By combining the VTA and the CA, we can reach a broader knowledge about both the what- and the how-aspect of learning in technical vocational education. We also argue that this method gives us a hint of how tacit knowledge can be taught in interaction. However,

more studies are needed to learn about the OoL, because the critical aspects that already have the right value in the interaction are not highlighted in the situation.

References

Aijmer, K. (1996). Swedish modal particles in a contrastive perspective. *Language Sciences*, *18*(1), 393-427.

Asplund, S-B. & Kilbrink, N. (2016). Learning how (and how not) to weld: Vocational Learning in Technical Vocational Education. *Scandinavian Journal of Educational Research* (accepted for publishing)

Bjurulf, V. (2008). *Teknikämnets gestaltningar: En studie av lärares arbete med skolämnet teknik.* (Karlstad University Studies, No. 2008:29). Dissertation, Karlstad: Karlstad University.

Bjurulf, V. (2012). "You'll just have to practice until you find your own way to do it!": A narrative study about how teaching is carried out in technical vocational education. *NorDiNa*, *8*(1), 17-25.

Björkholm, E. (2015). *Konstruktioner som fungerar: En studie av teknikkunnande i de tidiga skolåren*. Dissertation, Stockholm: Stockholm University.

Emanuelsson, J., & Sahlström, F. (2008). The price of participation. Teacher Control versus Student Participation in Classroom Interaction. *Scandinavian Journal of Educational Research*, *52*(2), 205–223.

Jones, A., Buntting, C. & de Vries, M. (2013). The developing field of technology education: a review to look forward. *International Journal of Technology and Design Education, 23*(2), 191-212.

Marton, F. & Booth, S. (1997). *Learning and Awareness*. New Jersey, Mahwah: Lawrence Erlbaum Associates Inc.

Marton, F. & Tsui, A.B. (Eds.) (2004). *Classroom Discourse and the Space of Learning*, Lawrence Erlbaum, Mahwah, N.J.

Sahlström, F. 2009. Editorial. *Scandinavian Journal of Educational Research, 53*(2), 103–111.

Sahlström, F. (2011). Learning as Social Action. In J.K. Hall, J. Hellermann & S.P. Doehler, (Eds.), *L2 interactional competence and development.* Bristol: Multilingual Matters.

Schegloff, E.A. (2007). *Sequence Organization in Interaction. A Primer in Conversation Analysis 1.* Cambridge: Cambridge University Press.

Vähviläinen, S. (2009). Problems in the Research Problem: Critical Feedback and Resistance in Academic Supervision. *Scandinavian Journal of Educational Research*, *53*(2), 185-201.

Females in Technology Education: The results of an ethnographic social-constructionist study in secondary schools.

Vicki Knopke
Griffith University
Brisbame, Australia
vickiknopke@bigpond.com.au

Abstract

This paper will present some of the results of a study undertaken in selected senior secondary schools in Queensland, Australia. The study examined the factors that encouraged and facilitated female student's participation and engagement in design and technology learning activities in technology education classrooms. Research on boys and masculinity has indicated that the social norms which have persisted over decades have not changed in relation to feminist views of teachers nor have the pushes for transformative approaches to gender in schools made a difference to practice (Keddie & Mills, 2007). The questions asked what factors have influenced female student's choices to take the subject? This explored effective classrooms, good practice, technology, gender and language and examined the socio-cultural approaches to learning that enable females to engage in technology education, as part of the STEM movement, in the 21st century. The second question examined how teaching and learning was conducted and approached in the technology classrooms which were examined. The final question asked what values were addressed in the teaching and learning in specific contexts of technology education for classes (Pavlova, 2009).

The study adopted an ethnographic social-constructionist stance which suggests that we acquire knowledge via the environment and gender relations that are socially constructed. The research used a qualitative case study methodology guided by a socio-cultural framework.

One of the recommendations was the need to build pedagogical ecologies for technology education based on an awareness of learning styles and values that are unique to females' ways of learning. Student backgrounds in terms of socio-economic experiences influence what female students choose to study within school settings. Life experiences and vocational aspirations of students contribute to student's study plans and their engagement in the learning area as they shape the 21st Century skills.

Key words: Gender, technology education, ecology of learning, education, curriculum, participation.

Introduction

This paper will focus on one recommendation from a doctoral research study undertaken in selected senior secondary schools in Queensland, Australia. The study examined the factors that encouraged and facilitated female student's participation and engagement in design and technology learning activities in technology education classrooms.

The research questions

Research on boys and masculinity has indicated that the social norms which have persisted over decades have not changed in relation to feminist views of teachers nor have the pushes for transformative approaches to gender in schools made a difference to practice

(Keddie & Mills, 2007). The research study was conducted using three research questions. The questions were; what factors have influenced female student's choices to take technology education classes as part of their senior school pathway? This question explored effective classrooms, good practice, technology, gender and language. These were regarded as the socio-cultural approaches to learning that enable females to engage in technology education, as part of the STEM (Science, Technology, Engineering and Mathematics) movement.

The second question examined how teaching and learning was conducted and approached in the technology classrooms in the study. The study investigated Year 11 classes in three schools. In doing so the ecology of learning environment, the context of the learning and social interactions were analysed and triangulated from staff, student and administrators perspectives.

The final question asked what values are addressed in the teaching and learning in specific contexts of technology education for those classes. This aspect examined the multifaceted interpretation of values and analysed the engagement of youth and the teaching staff with the concepts of values. This aspect drew on Pavlova's (2009) research of teaching and values. No study such as this had been completed in Australian schools prior to this research.

One recommendation from the research study was the need to build pedagogical ecologies for technology education. It is suggested that these learning ecologies are based on an awareness of learning styles and values that are unique to females' ways of learning (Knopke, 2015). Student backgrounds in terms of socio-economic experiences influence what female students choose to study within school settings. Life experiences and the vocational aspirations of students contribute to student's study plans. In turn their engagement in the learning area shapes what skills the students will develop which in turn shape their contribution to 21st Century skills. This paper will focus on this recommendation with respect to changing learning ecologies that will encourage more female participation.

Literature from Dakers and Dow (2009), Banks (2009), Murphy (2007), Weber and Custer (2005) note the importance of gender inclusion and a pedagogy which would cater to female learners in technology education. The last three decades has shown that too few a females have engaged in technology education despite the efforts of national education systems to implement programs for female participants. The research of Zuga (1996) concluded that females studying technology was important not just for the curriculum but for the value of the area itself. Lewis (1999) argued for further research to be undertaken.   Williams and Williams (1996), Petrina (2007) and Zuga (1997) found that the majority of research was about curriculum and little was about the gender, cognitive or cultural backgrounds of learning and teaching and learning in technology education. There was little research on students and teachers and the effectiveness of technology education (Petrina 1998, Zuga 1997). Martin and Ritz (2012) concluded that there was a need to address the issue of the low representation of females and minorities within the profession.

The UNESCO (2012) debates on gender parity at a school level set the context for this study. The feminist writings of Spender (1985), Rothschild (1983), Wajcman (2004), Talbot (2010) and Hill, Corbett and Rose (2010) have influenced the perspective behind this investigation. The empirical nature of their research laid the groundwork for this study. In

Australia, the publication of the first National Action Plan for the Education of Girls 1993-1997 is noted by Yates (1997) as emphasising the social construction of gender from the early years of school through an alignment that was to both syllabus and pedagogy. This movement did not sustain itself and was overtaken by a concern for boys in the equity debate. The focus had again turned from girls to programs such as the Boys Lighthouse Schools (Australian Government, 2003) and Success for Boys (Alloway & Dalley-Trim, 2006). A decade into the new millennium, concern for gender justice has been revised in Australia. Writers such as Connell, Fawcett and Meagher (2009) claim that neo liberal economic rationalism has shifted the focus of schooling to the *"production of future workers"*. Concerns about academic outcomes, client choice, and competition have further sidelined issues of social justice and pedagogy. Public culture and education reforms have come to reflect the dominant state ideology with equity being underpinned by mere rhetoric of democratisation (Blackmore, 2011). Ollis (2011) agrues that these practices have become embedded in our schools through lack of guidance and policy.

Siemens (2006) defines learning ecologies that promote learning in technology environments to contain seven elements for knowledge sharing. These elements are: flexibility, a tool-rich environment, consistency of practice and time, trust, simplicity decentralisation of learning and a high tolerance for experimentation and failure. Learning ecologies, to Brown (2000) are dynamic, living states. It is a social concept, a practice that is the social construction of reality which stems from humans as social beings acting on their interpretation and knowledge of reality. Learning ecologies can be further analysed as knowledge ecologies: open systems, that are both dynamic and interdependent, diverse, partially self-organising, adaptive and fragile (Brown, Collins & Duguid, 1989). A learning ecology is then a collection of overlapping communities of interest, cross pollinating with each other, and constantly evolving somewhat analogous to ecosystems such as rituals, response groups, individual class contexts and niches which are managed through the dependant role of members.

Gender as a term is a construct, not created by nature as a result of biology but rather created by and contingent on social and historical processes (Odenziel, 2003, Stanley, 1993). It is the bringing together of these concepts which can alter practices for female technology students relative to both curriculum and pedagogy in schools.

The following examines the methodology, and the results of the study. The paper concludes with a discussion on the outcomes that may heighten and encourage more females to participate in technology education.

Methodology

The study adopted an ethnographic social-constructionist stance which suggests that we acquire knowledge via the environment and gender relations that are socially constructed. The research used a qualitative case study methodology guided by a socio-cultural framework. Three case studies were undertaken.

The ethnographic method was used in the case studies to unpack learning and technology approaches within technology education classrooms. The goal in using an ethnographic case study was to give voice to the females who were part of the study in terms of why they choose to participate. Belenky, Clinchy Goldberger & Tarule (1986) spoke of the silence of women and the need to listen to the voices of constructivist women in order to alter the social landscape. The case study format is foremost in that it provides a

bounded study for each of the sites that were part of the study. Hoepfl (1997) in examining research paradigms focussing on the use of qualitative methodology argues for the responsible implementation of the research and a plausible connection between the observations and the conclusions drawn.

The qualitative investigative case study aimed to explore the factors which encourage and facilitate a greater participation of females in the area of technology education. The research was reported as separate case studies across three sites. The study was conducted as a case study, as outlined by Pole and Morrison (2003) and Campoy (2005).

The schools selected were those teaching senior secondary Technology/ Engineering Studies as a Queensland Studies Authority (QSA) registered subject. The specific schools selected had class sizes of 10 or more students and all had females as members of the classes. Students may elect, as part of their senior studies course, to join a Technology class for two years. Schools were accessible to the major city of Brisbane.

Participants

The research study examined three secondary school settings, each named as a site, which had female students in their technology education classes. Two of the case studies were publically funded (State Government) schools while one was a private school. The classes examined were post compulsory secondary students (Year 11 students) in their first year of a two year program of study. Students (male or female) of this age may leave school if they have employment. For the most part students choose to stay in school until they receive their senior certificate at the end of Year 12, the second year of post compulsory study.

In each site the participants included the students in the classes, the teacher and the Head of Department (HOD). The HOD was a managerial role overseeing programs of study and student allocations as part of the school administration team. The students were aged 15 to 17 years. The teachers were trained Design and Technology teachers. The following table lists the numbers of participants.

Table 1 Numbers of participants in each site.

Sites	Class totals	Female Students	Teachers	HOD
1	22	1	1	1
2	26	2	2	1
3	15	2	2	1

The study aimed to interview four female students in each class, their teachers and an administrator. In the first school (Site 1) there was one female student in the selected class. Two females were present in a Year 12 class, and more female students in a year ten class - a younger compulsory age class. All were observed and interviewed using the same interview and question schedule however the focus of the study remained on the single female in the Year 11 class. Site 2 had two female students and Site 3 began with more however two female students remained for the duration of the study. Site two and three had two teachers and a male HOD. All participants were observed and interviewed using the same question schedules and observed in the context in which they were teaching, learning or administering.

The researcher took the role of participant observer and visited the case study sites over a six month period. Classes were scheduled across each week and the researcher arrived in each school in time for specific scheduled classes related to the unit they were working on.

Data collection instruments

The data for each case study were analysed through four data sets. These were interviews, observation data, audio recordings, and photographs taken by the researcher. No video recording was permitted. The interviews included conversations with the participants; the teachers in each of the case studies, and the HOD's. The same research process was used in each of the sites for all of the participants.

An interview schedule was developed for the students and another for the teachers and HODs. The schedules corresponded to the three research questions in the study. The same research process was used in each of the sites however the nature of the study meant that there needed to be some flexibility accorded to individual locations and the activities in the sites. A review of the observation notes and data was completed as soon after each visit as possible. Transcripts of the recordings were made and coded according to the seven classifications used for all of the data.

Data which emerged from the collection process was coded and analysed through seven lenses used in the research study in the same manner for each case study. Differences emerged due to the nature of each school and the participants despite the same research methodology being applied. The research lenses were; learning ecologies, gender and technology education, language, motivation, role modelling and peer support, socio-cultural approaches to learning and finally values.

Results

The ecology lens looked for common learning factors that would best suit female technology students. Common factors which emerged from each of the case studies were:

- Building interrelationships with others was most important,
- Maintaining positive relationships with staff,
- invisioning possible futures,
- understanding the breadth of jobs that technology can afford,
- broadening ones view of STEM through having built ones confidence,
- familiarity with the subject area and
- being accepted into a community of practice, and
- adding social value to the community the students lived in.

These factors contributed to positive female engagement in the technology learning ecology.

Students identified that the interrelationships in their learning environment helped shape their behaviour and development within the technology context. Positive relationships with staff and students enabled females, as well as their peers, to interact and develop in a supportive, trusting environment.

One student saw practical opportunities in the field of technology for herself as a possible future. She was well aware of construction opportunities and the breadth of jobs that could be undertaken as a result of engaging with technology education and expressed

this as the ability to; *build your own stuff.* In a later interview she added *that may also include houses*.

Other female students saw the academic possibilities emerging from technology education in terms of STEM subjects and particularly engineering but few held a broad world view of limitless possibilities into the future. The student in Case study 1, towards the end of the course saw the technical skills learned as those she would use later on.

The focus of the instructional studies from the teaching staff was on technical construction skills. As the female students became familiar with the workshop areas and the physical tools they interacted well with the staff and other learners as their confidence and in turn, performance appeared to improve. Whilst some female students were able to use their organisational skills to have others complete the mundane tasks such as attaching a lid with a screw or gluing on a frame, they did not quantify these management skills into applications that may be useful beyond the classroom.

Identifying with a community of practice which formed the learning environment was important to the female participants. This factor catered to the female essence of belonging and identification (socially) with the group and facilitated their learning. The final result from learning within the technology studies environment was its social contribution. Students appeared to value service projects that were recognised and contributed to the communities they were part of. As learners they were motivated to further engage to achieve a social objective. The following discussion demonstrates the results which emerged from the study.

Discussion

The results indicated that what was important were the social contribution which learning in technology provided. Adding value to the community of learners as part of a valued group of skilled people appeared to make a difference to the engagement of the female learners. Establishing positive relationships with participants (teachers and peers) in the environment emerged as one of the key factors that would heighten the participation of female students. Recognition of the need for support and understanding of female learners and their unique learning styles such as the need to discuss issues, emerged frequently. The third result was the role of supporters in technology environments. For some participants this was a past female teacher who had left a positive legacy in the Technology department of that school. For others it was a male peer or teacher. Knowing that there is a community aspect to learning in technology catered to the female notion of service and projects which contributed to positive community outcomes. These factors were given higher value by female students than more technical work. The final result was in developing skills in problem solving and thinking skills that could be transferred to other contexts. Learning within a techno-social sphere where there are positive social interactions may be the best environment for females. Research of Nystrand et al. (1998), Schawb (2013) and Siemens (2006) into effective classrooms and good practice supports the findings for what is a potentially marginalised group.

One finding was the need to build on learning styles suited to female students. The social, creative and cognitive aspects are important in developing confidence with female students who were moving into what was initially, an unfamiliar learning environment (Knopke, 2015). These findings are consistent with those of Hawley (1986) and Tembone (2008) who argue that the ecology of learning in technology education classes must

embody the pedagogical strategies that incorporate more females. Providing a structure which the female learners could identify with and be guided by, was found to enable female students to become self-directed learners, gaining confidence to engage in the technology process, realise a design, and transform it into an artefact.

Support of female teachers and peers appeared to make a difference to the participation of some of the female students. As the female students felt comfortable within the learning environment they actively engaged in becoming familiar with specific technical terms through discourses conducted at the workbenches. In finding their own identities in the workshops the female students engaged and participated in the workshops. De Vries, Custer, Dakers and Martin (2007) writing on institutional design, noted the need for varied teaching approaches and practices which accommodated differing learning styles, interests, prior knowledge, comfort zones and socialisation needs.

Techniques used by skilled teachers (Case study 2) motivated students in their classes. Of specific appeal to the female students was the pedagogy which provided a structured program that encouraged learning styles which female learner's best engaged with. Clear scaffolding provided problem solving avenues from which flowed project and time management skills and planning that the female learners excelled in. The apparent freedom to learn within what was a sophisticated structured environment did motivate the female students to excel. This is consistent with Hattie's (2009) claims that student motivation is at its highest when students are competent, have sufficient autonomy, get feedback, set meaningful goals and are affirmed by others. Females will take on internal motivational factors ahead of males who will externalise their academic achievements (Hattie, 2009).

Case study 3 demonstrated that positive learning environments made a positive difference to the female students and their willingness to engage in technology education learning. Feelings of support and the notion of feeling special and unique in a service oriented activity appeared to enhance the engagement of female students. Research by Blackmore (2011) on feminist educational thinking suggests that the discourses of educational change since the 1990's have helped promises for feminism and that the transformation for women in education have brought about changes in social relationships. "In an era of post masculinity, women need to exhibit strength, strong relations, care and collegiality" (2011, p 208). Keddie (2012) in her feminist critiques proposes that it is the political agenda which needs to be addressed before the gender divide can be meaningfully changed.

Conclusion

The study found that a planned female appropriate pedagogy through a structured curriculum has an impact on female students' engagement. Student backgrounds and socio-economic status influenced what they choose to study within school settings. Life experiences and vocational aspirations contributed to the female students' study plans. Having knowledge of the benefits of the subject area, the thinking skills, physical skills and the pathways which the learning may afford participants appears to make a difference to female choices. These are the values orientations as championed by Pavlova (2009).

A female-oriented ecology that promotes a pedagogy that mixes learning styles with structured teaching along with the independence to problem solve and discuss issues is

an undervalued aspect of teaching in technology education. The worth of the output and its social value is part of the criteria that female students use to judge the relevance of courses. More emphasis and focus on values and sustainability should appeal to female participants. Broadening the information base about technology education will further expand its appeal to potential female participants.

The quantity of data collected was significant however the study was undertaken over only one semester. There is room for a longitudinal study which could follow the longer term development of the female participants. Limitations included the lack of female students and the location of these schools as urban rather than rural - urban mixed environments which may have different female participation rates.

Gender support and role modelling is the factor which appears to heighten female participation. It is the combination of curriculum content, pedagogy and cognitive challenges in a safe and supportive environment – the learning ecology that matters. The importance of relationships and acknowledging difference is the key to the plurality of the approach recommended to technology educators. Only by increasing the numbers of females through altering the traditional approach to learning via learning styles that reflect values and relationships can we promote technology students for the 21st Century for jobs that we have not yet imagined.

References

Alloway, N., & Dalley-Trim, L. (2006). *Success for boys: Helping boys achieve, boys and literacy*. Carlton South, Vic.: Curriculum Corporation Retrieved from http://eprints.jcu.edu.au/9601/1/9601_Alloway_2006_front_pages.pdf.

Australian Govenment. (2003). *Boys' education lighthouse schools* Retrieved from http://www.deewr.gov.au/Schooling/BoysEducation/Pages/bels.aspx.

Banks, F. (2009). Research on teachiang and learning in technology education. In Jones A.T & M. J. deVries (Eds.), *International handbook of research and development in technology education* (pp. 373-389). Rotterdam Sense.

Belenky, M. F., Clinchy, B., Goldberger, N., & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, voice, and mind*: Basic Books.

Bijker, W. E. (1995). *Of bicycles, bakelites, and bulbs: Toward a theory of sociotechnical change*. Cambridge, Massachusetts: MIT Press.

Blackmore, J. (2011). Leadership in pursuit of purpose: Social, economic, and political transformation. In C. M. Shields (Ed.), *Transformative leadership: A reader* (pp. 21-36). New York: Peter Lang

Brown, J. S. (2000). Growing up digital, how the web changes work, education, and the ways people learn. *Change: The Magazine of Higher Learning, (New Rochelle, N.Y.),, 32*(2), 11 - 20.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Education Researcher, 18*(1), 32-42.

Campoy, R. (2005). *Case Study Analysis in the Classroom: Becoming a Reflective Teacher*. Lonodon: Sage.

Connell, R., Fawcett, B., & Meagher, G. (2009). Neoliberalism, new public management and the human service professions: Introduction to the special issue. *Journal of Sociology, 45*(4), 331-338. doi: 10.1177/1440783309346472

Dakers, J. R., & Dow, W. (2009). *Understanding and providing a developmental approach to technology education, *. Glasgow: University of Glasgow.

De Vries, M. J., Custer, R., Dakers J., & Martin, G. (2007). Differentiation in the technology education classroom. In M. J. De Vries, R. Custer, J Dakers & G. Martin (Eds.), *Analysing best practices in technology education* (pp. 235- 245). Rotterdam: Sense.

Hattie, J. (2009). *Visible learning*. Oxon: Routledge.

Hawley, A. H. (1986). *Human ecology: A theoretical essay*. Chicago: The University of Chicago Press.

Hill, C., Corbett, C., & Rose, A. S. (2010). Why so few? Women in science, technology, engineering, and mathematics (pp. 134). Washington, DC: AAUW.

Hoepfl, M. C. (1997). Choosing qualitative research: A primer for technology education researchers. *Journal of Technology Education, 9*(1, Fall 1997), 47-63.

Keddie, A. (2009). National gender equity and schooling policy in Australia: struggles for a non-identitarian feminist politics. *Australian Educational Researcher, 36*(2), 17.

Keddie, A. (2012). *Educating for diversity and social justice*. Routledge

Keddie, A., & Mills, M. (2009). Disrupting masculinised spaces: teachers working for gender justice,. *Research Papers in Education, 24*(1), 29-43. http://www.tandfonline.com/doi/pdf/10.1080/02671520801945834

Keddie, A., & Mills, M. (2007). Teaching for gender justice. *Australian Journal of Education*, *51*(2), 205-219.

Knopke, V. (2015). Factors that encourage and facilitate female students to participate and engage in Technology Education, PhD thesis, Griffith University. Australia.

Lewis T. (1999). Research in technology education - some areas of need. *Journal of Technology Education, 10*(Number 2).

Martin and Ritz (2012)

Martin, G., & Ritz, J. (2012). Research needs for technology education: A u.S. Perspective. *Journal of Technology Education, 23*(2), 25-43.

Murphy, P. (2007). Gender and Pedagogy. In D. Barlex (Ed.), *Design & Technology for the next generation* (pp. 236-251). England: Cliffeco.

Nystrand, M., Gamoran, A., & Carbonaro, W. (1998). Towards an ecology of learning: The case of classroom discourse and its effects on writing in high school english and social studies. New York: National Research Center on English Learning & Achievement University at Albany State University of New York.

Oldenziel, R. (2003). Why masculine technologies matter. In N E Lerman, R Oldenziel & A. Mohun (Eds.), *Gender and technology* (pp. 37-71). Maryland: Johns Hopkins University Press.

Ollis, D. (2011). A respectful relationships' approach: Could it be the answer to preventing gender-based violence? *Association of Women Educators*(2011), 19 -26.

Pavlova, M. (2009). Conceptualisation of technology education within the paradigm of sustainable development,. *International Journal of Technology and Design Education,, 19*, 109-132. doi: 10.1007/s10798-008-9073-5

Pole, C., & Morrison, M. (2003). *Ethnography for Education*. England: Open University Press.

Petrina, S. (1998a). Men at work: Inspecting the foundations of technology education. *Journal of Technology Education, 36*(1), 99-121.

Petrina, S. (2007). *Advanced teaching methods for the technology classroom*. Hershey: Idea Group.

Rothschild, J. (1988). *Teaching technology from a feminist perspective: A practical guide*. New York: Pargamon Press Inc.

Schwab, J. J. (2013). The practical: A language for curriculum. *Journal of Curriculum Studies, 45*(5), 591-621. doi: 10.1080/00220272.2013.809152

Siemens, G. (2006). Learning Ecology, Communities, and Networks: Extending the classroom. Retrieved from http://www.elearnspace.org/Articles/learning_communities.htm

Smith, M. K. (2003, 2009). Jean Lave, Etienne Wenger and communities of practice. *the encyclopedia of informal education*. www.infed.org/biblio/communities_of_practice.htm.

Spender, D. (1985 ed.). *Man made language*. London; Boston: Routledge & Kegan Paul.

Stanley, A. (1993). Mothers and Daughters of Invention: Notes for a revised History of Technology. In Hopkins (Ed.), *Sex/Machine* (pp. 708). Bloomington: Indiana University Press.

Stanley, A. (1995). Women Hold Up Two-Thirds of the Sky. In J. Rothschild (Ed.), *Mothers and Daughters of Invention: Notes for a Revised History of Technolgy, Machina ex Dea: Feminist Perspectives on Technology*. New Brunswick, NJ: Rutgers UP.

Talbot, M. (2010). *Language and Gender* (2 ed.). Cambridge: Polity.

Tembon, M. (2008). Overview. In Mercy Tembon & Lucia Fort (Eds.), *Girl's education in the 21st century, gender equality , empowerment and economic growth* (1 ed., pp. 3 - 21). Washington: The World Bank.

UNESCO. (2012). Education For All Global Monitoring Report.   Retrieved 28 May 2012, from http://www.unesco.org/new/en/education/themes/leading-the-international-agenda/efareport/reports/20034-gender/

Wajcman, J. (2004). *Technofeminism*. Cambridge, UK: Polity Press.

Weber, K., & Custer, G. (2005). Gender-based preferences toward technology education content, activities, and instructional methods. *Journal of Technology Education, Vol. 16* (No.2), 55-69.

Williams, J. P. (2011). Research in technology education: Looking back to move forward. *International Journal of Design Education, 7*(May 2011), 1- 9. doi: 10.1007/s10798-011-9170-8

Williams, J., & Williams, A. (1996). *Technology education for teachers*. South Melbourne: Macmillan.

Yates, L. (1997). Gender equity and the boys debate: What sort of challenge is it? *British Journal of Sociology of Education, 18*(3), 337-347. doi: 10.1080/0142569970180302

Zuga, K. F. (1996). Reclaiming the voices of female and elementary school educators in technology education. *Journal of Industrial Teacher Education, Vol. 33*(No. 3).

Zuga, K. (1997). An analysis of technology education in the united states based upon an historical overview and review of contemporary curriculum research. *International Journal of Technology and Design Education, 7*(2), 203-217.

Zuga, K. F. (1999). Addressing women's ways of knowing to improve technology education environment for all students. *Journal of Technology Education, Vol 10*(Number 2), 1- 11.

Exploring students' documentation with mobile devices when designing and constructing a bridge model in technology education

Tiina Leino Lindell; Stefan Hrastinski
KTH Royal Institute of Technology
Stockholm; Sweden
Leino@KTH.se; Stefan.Hrastinski@KTH.se

ABSTRACT

The ability to master information and communication technology (ICT) in problem-solving activities, is a central 21-century skill. The objective of this study is to explore the role that students' documentation with mobile ICT plays in their problem-solving activities. This, when compulsory school students design and construct a bridge model in technology education. The following research questions are defined and examined: 1) Which actions do students take using mobile ICT to document their problem-solving activities? 2) What function will students' documentation using mobile ICT have in their problem-solving activities? These questions have been explored by means of activity theory and qualitative methods. The results show that the two participating students document their work by photographing. Although the task included continuous documentation, this was not performed regularly by the students. Furthermore, the documentation did not contribute with any supportive function to their problem-solving activities during lessons. Instead the documentation task has caused contradictions. By highlighting these contradictions, this study contributes with understanding of possible challenges when introducing mobile ICT for documentation.

Keywords
21-century skills, documentation, mobile device, ICT, technology education, problem-solving

INTRODUCTION
The ability to master the use of Information and Communication Technology (ICT) in problem-solving situations has been mentioned as a vital attribute of 21st century skills (e.g. Ananiadou & Claro, 2009; European Commission, 2013). In technology education there are examples of research projects where mobile ICT has been used to document problem-solving activities. The focus has mainly been on the assessment aspects of the documentation (e.g. Kimbell, 2012; Hartell & Skogh, 2015). Aside from assessment, documentation can also support students' problem-solving processes. An example of this is the importance of documentation in design processes, as this can help students to reflect on their own results (Hargrove, 2013; Doppelt, 2007). In order to complement previous technology education studies, which focused on assessment aspects, the objective of this study is to explore the role that students' documentation using mobile ICT plays in their problem-solving activities. This study therefore also takes account of how students' documentation is formed by the context of the lessons. In order to meet the objective, the following research questions are examined: 1) Which actions do students take using mobile ICT to document their problem-solving activities? 2) What function will students' documentation using mobile ICT have in their problem-solving activities?

These research questions are investigated in an activity in which students in compulsory education design and construct a bridge model in technology class. In addition, students were required to document their work on tablets or smartphones. For the purposes of this study, mobile ICT include smartphones and tablets. The written description of the assignment states that students shall; document why they have chosen to build the specific type of bridge and describe which materials and colors they intended to use. The students also got verbal instructions to document their work continuously, during their problem-solving activity. During the task, designed by the students' teacher, the students should be working in pairs or small groups. This report is a sub-study in a research project that investigates how students at a Swedish compulsory school use mobile devices in relation to school assignments.

In Sweden, it is common for students in technology education to be given problem-solving assignments in which they are required to document their work. Blomdahl (2007) states that students' problem-solving often has a practical nature when they are supposed to use various forms of representation such as sketches, models and documentation to visualize their understanding of the subject. Alasuutari, Markström and Vallberg-Roth (2014) states that documentation in education is a way of collecting information that may be either electronic or non-electronic. According to her, documentation can include video, photographs, notes, observations, interviews, sound recordings, etc.

If one examines the Swedish compulsory school syllabus for technology, documentation is described as partly a working method and partly a knowledge requirement (The Swedish National Agency for Education, 2011). As students develop technical solutions, they must document their work with the aid of manual and digital sketches and technical drawings, or with physical or digital models. The knowledge requirement for Year 9 is that the students' documentation must make clear the intention behind their work. The use of the term documentation in relation to this subject is new to the current syllabus.

PREVIOUS RESEARH

In technology education research, the term documentation has been used to describe both the end-product and the process itself. For example, Hargrove (2013) states that students put much more work into the documentation of their products than the documentation of their process. He contends that students often have fixed representations of the end-product, while documentation to explain their solutions is flawed. An Israeli research project describes in a similar manner that documentation may include both the students' process and end-product (Williams, Iglesias, & Barak, 2008). It has been noted that students fail to reproduce the entirety of their problem-solving process in their documentation. One explanation may be that students feel that documentation should show the end-product at its best. Another explanation is that technology teachers do not see documentation as a means for learning and reflection.

The previous research carried out on documentation using mobile ICT in technology education has, as already mentioned, largely focused on assessment (e.g. Hartell & Skogh, 2015). In this study, texts, drawings, photographs and sound recordings used by the students were collected in an e-portfolio, to be assessed later. A similar approach was used in the British research project e-scape (Kimbell, 2012). In this project, students have been asked to photograph during their problem-solving process using tablets. As a supplement to these photographs, the students have been asked to make sound recordings in which they described what has gone well and what they needed to develop further. At the end of the activity the students were also able to reflect on the actions they had taken during their work. In response to a questionnaire, 94% of the students replied that they agreed that it had been a benefit to make these "photo storylines".

In the various examples, we can see that it is possible to use documentation in many different ways. In this study, the concept of documentation covers the information that students collect with the aid of mobile ICT. Mobile devices can be used to handle different types of information, for example photographs, notes, video, etc. Therefore, this study includes all forms of representation that can possibly be used to collect information using tablets and smartphones. Documentation covers both information collected and used during the problem-solving process, as well as information describing the students' end-product.

THEORETICAL FRAMEWORK

The study is based on Engeström's activity theory with roots in a cultural-historical theoretical tradition (Engeström, 1999). Within this theory humans' use of tools are central issues. It is a descriptive theory that serves as a framework to gain insight in people's actions in context. In other words, students' actions with mobile devices are not confined to individuals, rather they are considered to be influenced by the situations they are used in. In addition, students' mobile use also can affect its context. To exemplify, a class might have been given the problem-solving task to design and construct a bridge model, as a group work. During the activity one student uses a mobile phone to look at and reflect upon a picture illustrating a bridge construction. This picture will later on also be used by the group as an inspiration to their own bridge construction. In this way, the student's mobile use has affected the groups' problem-solving result. The action has thereby also undergone a transformation from an individual mobile use, to contribute meaning to the students' unified problem-solving *outcome*. Hence, the action can be explained as a transformation from an individual-level to the contextual *activity-level*. By the means of activity theory students' mobile use can be understood at three different levels.

Figure 1
Levels of actions

Activities - Motive
Actions - Goal
Operations - Instrumental condition

As can be seen in Figure 1, the earlier mentioned *activity-level* is the highest level. At this *activity-level*, an action has a *motive* that relates to the group's shared objective for the activity. Moreover, students might also use mobile phones at an *action-level* and an *operational-level*. At an *action-level* the individuals have their own goals for their actions. In our example, the student's goal for watching the image on the mobile phone might have been to contribute to the groups' problem solution. Another alternative could have been that the student instead used her mobile entirely aimlessly, without any goal. In that case, the action should be understood as an *operation*. Actions at the *operation-level* are the lowest level of actions, because they are taken with instrumental conditions. During an activity an action taken at an *operation-level*, can be transformed to an *action-level* with personal goals. Moreover, it might also be transformed to an action with a shared motive at an *activity-level*. In this manner, personal interests can be understood in these levels of actions.

It is not guaranteed that all students' actions with mobile devices will contribute with meaning to their problem-solving results. Instead, these actions might have a role lined with conflicts during the activity. Activities contain different kinds of conflicts. By being conscious of these we can gain understanding of the challenges involved in the activities. These *contradictions* can explain why mobile actions fail to contribute meaning to the problem-solving results. Unpacking these *contradictions* therefore provide a potential

development in shaping future problem-solving tasks. The activity's history is created through the actions taken. It is by investigating patterns of behavior beneath activities, we gain understanding of how the activities are shaped.

METHOD

The sample for the study consists of two students in Year 9 of a Swedish compulsory school. A purposeful sampling method has been used, based on criterion sampling (cf. Coyne, 1997; Ritchie, Lewis & Elam 2013). This means that the students have been selected due to access to own mobile phones. Additionally, they were chosen because they had written consents from their parents. The received consent has been an important sampling criteria, as it is an ethical rule imposed by the Swedish Ethical Review Act.

Data collection has mainly been carried out during six technology lessons over the course of six weeks. Qualitative methods have been used to analyze the types and function of documentation activities the students do using mobile devices. These have included observations, video documentation and audio recordings. As it can be problematic to see what students are doing with small mobile devices (cf. Brown & Laurier, 2013), the method has also been complemented with interviews after each lesson (Fox-Turnbull, 2009; Coiro, 2008). In addition, two further supplementary interviews have been carried out after the conclusion of their problem-solving task, by using stimulated recall (Gass & Mackey, 2000; Fox-Turnbull, 2009). All interviews were recorded and systematically transcribed based on the research objectives and theoretical framework (cf. Derry et al., 2010). Then, the students were asked to describe and reflect on their actions with mobile devices by watching the video-data and at their mobile documentation.

ANALYSIS

To begin with, the analysis have investigated which types of documentation actions that have been conducted by the students using mobile devices. This have been done, by analyzing if students have been audio recording, photographing, videotaping, texting etc. Secondary, we examined the function of students' documentation in relation to their problem-solving activity. In order to do this examination, we analyzed at which level the students' actions have been taken. Have these been taken at an *operation-level*, *action-level* or *activity-level*? If an action has been taken at *activity-level* we have also highlighted if it has contributed meaning to the students' problem-solving outcome and in that case, what meaning? However, if an action instead has been taken at an *action-* or *operational- level*, we analyzed if the documentation action played any other role in the activity. If so, we have highlighted if the actions have shaped conflicts in the activity. This has been made by analyzing *contradictions* that can be linked to the documentation action (see Figure 2).

Figure 2
Analysis schedule

1. **Which actions do students take using mobile ICT to document their work?** - *Have they been wrighting, photographing, videotaping etc.?*

2. **What function will students' documentation using mobile ICT have in their problem-solving activities?** - *Have actions been taken at activity-, action- or operational-levels?*

2.1 **Action at activity-level** - *What meaning has been projected to the students' problem-solving outcome?*

2.2 **Action at action- or operation-level** - *Which contradictions can be connected to students' documentation actions, during activities?*

RESULTS

6.1 Documentation actions with mobile devices

During the problem-solving activities, the students carry out one documentation action connected to the task. This consists of an action when one of the student's photograph

their bridge model. The action takes place during the third lesson, at the request of the teacher, who reminds the students to photograph their work:

Excerpt 1
Students' actions with mobile ICT and the taken photograph

Actions with mobile devices	Verbal articulations
	Teacher 2: Hey guys. Don't forget to photograph your work.
	Teacher 2: There's only five minutes left, so we will begin to clean up. If you don't have a camera, you can use this iPad.
Sarah: Taking Emma's mobile. Takes a photograph	

In the excerpt, Sarah can be seen photographing the bridge model with a mobile phone after the teacher specifically asks them to photograph their work.

6.2 The function of the documentation

Taken documentation in relation to students' problem-solving outcome. During the problem-solving activities at lessons, the students made no use of the taken photograph. In other words, it has not contributed meaning with regard to the students' design or construction of the bridge model. The photographic action has in that sense not been taken at an *activity-level*. At the follow-up interview, Sarah gives the following explanation to why she took the picture:

Researcher: Why did you do it [take a photograph]?
Sarah: Because she told me to.

As can be seen in the quotation, the student states that she has taken the picture because the teacher asked her to do so. In relation to their problem-solving activity, the student expresses no goal of her own behind why the picture was taken. Therefore, the photographic mobile use has been categorized as an action at the *operational-level*. Moreover, this action has never been transformed to the students' *activity-level* during lessons at school. This can, for example, be seen in a follow-up interview held some weeks after the end of the problem-solving activity. The students were asked whether they ever used the mobile phone photograph at any time, for any objective:

```
Researcher: Have you ever used the photo for anything?
Sarah:      Like what?
Researcher: Anything at all. Have…have you, you know,
            looked at it or done anything with it or…
Sarah:      Eh…We showed it to [laughs]
Emma:       Parents.
Researcher: I see.
Sarah:      Parents.
Researcher: Well, that's nice. And you did that because…?
Sarah:      Just to show how…you know, how we built it
            and so on.
```

The excerpt show that the photograph has been used outside but not inside school. Then, both students have used the picture to present and tell their parents how they constructed the bridge model. In this way the students have been able to share their experiences from technology education with their parents. This was done after the completion of the model.

Contradictions during the problem-solving activities. The documentation action has not contributed meaning to the outcome of the students' problem-solving, during lessons. However, the action has had a function as it has created contradictions during the students' problem-solving work.

If one looks at how the operative mobile action has taken shape during the activities, one can see several contradictions that are interconnected with the documentation task. The most expressed contradictions have been about students' understanding concerning the documentation task. During the activity, the students express that they are unsure of the objective of the task. During the first and second lessons, a teacher describes verbally several times for the students that they should document their work using their tablets or smartphones. It is possible to see that the students are uncertain of the meaning of the task. This is expressed during the first lesson for example, when the students read the written description. At this point, Sarah asks what is meant by the instruction to document their work: "Document this by using a mobile. Document, what? "The students have also attempted to obtain an answer about what is meant when they are told they should document by asking the teacher: "Hang on, what do you mean by document?" Emma asks this question during a discussion on materials during the first lesson. However, the question goes unanswered during the discussion. It is also apparent from a follow-up interview that the students are unsure about what document means:

```
Researcher: There is a word I've been thinking
            about. If you were to describe to document,
            how would you explain the term?
Sarah:      To document? Well…[laughs]
Emma:       [laughs] I don't know.
Sarah:      What I mean is, I understand but not really.
            To document, well, that's, isn't
            it to… that you write about the thing sort of.
Emma:       It makes me think of those documentary
            films [laughs] that kind of thing.
```

In the quote above, Emma initially says that she does not know how to describe the term. Later she says that she associates documentation with documentary films. Sarah says that she partly understands the meaning of the concept and that she associates it with written descriptions.

During problem-solving activities, two other types of contradictions also occur. One is that during the first lesson, students would rather use the school's tablets for the task, as they have larger screens. However, the tablets were not available as they were being used by another class. Another contradiction is that the teacher has expressed concern that

students will use their phones to document during her introduction at the beginning of the second lesson. This was expressed by the teacher when she gave order to the students to not use their mobiles during her lecture.

DISCUSSION
7.1 Documentation actions with mobile devices
The results show that students take one photographic action with their mobile-ICT during the problem-solving activity at school. By the means of activity theory, the action has been understood as action at an *operational-level*. This means that the student has had no goal of her own for why she did the documentation in relation to their problem-solving activity. Furthermore, the students only take one photograph for documentation, when the task explains that they are to document during their activity. In common with previous studies, this illustrates that students invest very little time or engagement in documenting their problem-solving process (Hargrove, 2013). One explanation for this phenomena might be that students do not understand the objective of the documentation. The lack of a personal goal can be another key to why photography with mobile devices, in this study, fails to contribute meaning to the students' problem-solving outcome during lessons.

7.2 The function of documentation
The documentation taken with mobile devices has not had any supporting function for students' problem-solving in the classroom. Instead, the documentation task has been fraught with contradictions during the activity. The results contrast from Kimbell's study (2012) in which students expressed the positive effects of using photo-storylines. The fact that students do not use their documentation for reflection in school is also opposed to Doppfelt (2007). One reason for the differing results may be that the structure for documentation, as well as information about its objective, has been unclear in this study. Students were for example never informed of what they were expected to do with this documentation. Maybe the teacher's intention with the documentation was to use it for assessment, like other studies have shown examples of (cf. Hartell & Skogh, 2015)? However, the results indicate that documentation tasks may need to be more structured if they are to contribute meaning to problem-solving results. One reason behind the unstructured nature of the tasks might be that the teacher does not see documentation as a means of learning and reflection during the activity (Williams, Iglesias, & Barak, 2008)? Even if this study provides no definitive answers on the issues in this paragraph, results indicate that it will not be effective to introduce documentation tasks using mobile devices in whatever manner.

One contradiction during the activities is the interpretation of the term documentation. The results show that teacher and student can have different understandings of what the term covers. Perhaps it is not so strange that the concept is interpreted differently when it is used in such a variety of ways at a community level (cf. The Swedish National Agency for Education, 2011; Blomdahl, 2007; Hargrove, 2013)? The lack of explanation of the term documentation may be a reason behind the existed contradictions. It is also interesting to note that the students do take a photograph after the teacher asks them to *photograph* instead of *document*. Additionally, one cannot see any more contradictions concerning the concept of documentation after this photographic action.

Other reasons why the documentation activities with mobile devices were not carried out on more occasions may also include the lack of tablets for students. It has been declared that the small screen size of mobile phones can be problematic in learning situations (Kukulska-Hulme, 2007). The fact that there are different rules for teachers and students as to when documentation activities using mobile devices can be carried out, might be

another challenge when implementing mobile devices for documentation in problem-solving tasks.

CONCLUSION, LIMITATIONS AND CONTINUED RESEARCH

In an era when the ability to master ICT in problem-solving is a central competence for the future, this study shows that the photographic documentation action of the participating students have failed to contribute meaning to their problem-solving results. With this research, we have contributed knowledge of possible causes of the non-supporting function. Although this study is based on two students during a specific problem-solving task, the ambition has been to gain a deeper understanding of the underlying factors. This has been done by careful analysis of what the students and teachers have done and said during all lessons and interviews. By highlighting conflicts during lessons we have seen some reasons behind the non-exploited use and the lack of documentation actions. The qualitative study, with its small sampling size also makes it difficult to draw any general conclusions. At the same time, thanks to the method, it has been possible to see and understand how structures and clarity might be important factors to take into consideration when implementing mobile devices in documentation tasks.

In addition, the study indicate that we require greater knowledge and a continued discussion about the concept of documentation. Perhaps the term needs to be developed to include more categories, thereby bringing clarity to the meaning of what is being described and discussed? One important area for continued research is to obtain more knowledge about the intentions of teachers with regard to the documentation task. In addition, the study opens the door to an investigation into how documentation with mobile devices can offer students the opportunity to discuss and reflect on their problem-solving activities beyond the school gates.

References

Alasuutari, M., Markström, A. M., & Vallberg-Roth, A. C. (2014). *Assessment and documentation in early childhood education*. Routledge.

Ananiadou, K. and M. Claro (2009), "21st Century Skills and Competences for New Millennium Learners in OECD Countries", *OECD Education Working Papers*, No. 41, OECD Publishing, Paris. DOI: http://dx.doi.org.focus.lib.kth.se/10.1787/218525261154

Blomdahl, E. (2007). Technology in the classroom: a study of technology education for younger children in compulsory school. 215. Stockholm: HLS Förlag.

Brown, B., & Laurier, E. (2013). "Mobility, Maps and Mobile Device Use.". *Proceedings of CHI 2013* (pp. 1-10). Paris, France: ACM Press.

Coiro, J. (Red.). (2008). *Handbook of research on new literacies.* New York: Lawrence Erlbaum Associates.

Coyne, I. T. (1997). Sampling in qualitative research. Purposeful and theoretical sampling; merging or clear boundaries?. *Journal of advanced nursing*, *26*(3), 623-630.

Derry, S. J., Pea, R. D., Barron, B., Engle, R. A., Erickson, F., Goldman, R., & Sherin, B. L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology, and ethics. *The Journal of the Learning Sciences*, 19(1), 3-53.

Doppelt, Y. (2007). Assessing creative thinking in design-based learning. International Journal of Technology and Design Education. DOI: 10.1007/s10798-006-9008-y.

Engeström, Y. (1999). Activity theory and individual and social transformation. . i Y. Engeström, R. Miettinen, & R. Punamäki (Red.), *Perspectives on activity theory.* (pp. 19-38). Cambridge: Cambridge Univ. Press.

European Commission. (2013). *Survey of schools: ICT in Education. Benchmarking access, use and attitudes to technology in Europe's (2013), (accessed October 5, 2013).* Retrieved

from https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/KK-31-13-401-EN-N.pdf

Fox-Turnbull, W. (2009). *Stimulated Recall Using Autophotography - A Method for Investigating Technology Education.* Christchurch, New Zealand: University of Canterbury.

Gardner, P. L., & Hill, A. M. (1999). Technology education in Ontario: Evolution, achievements, critiques and challenges. Part 1: The context.*International Journal of Technology and Design Education*, *9*(2), 103-136.

Gass, S. M., & Mackey, A. (2000). *Stimulated recall methodology in second language research.* Mahwah, N.J: Lawrence Erlbaum Associates.

Kukulska-Hulme, A. (2007). Mobile usability in educational contexts: what have we learnt?. *The International Review of Research in Open and Distributed Learning*, *8*(2).

Kimbell, R. (2012). Evolving project e-scape for national assessment.*International Journal of Technology and Design Education*, *22*(2), 135-155.

Hargrove, R. A. (2013). Assessing the long-term impact of a metacognitive approach to creative skill development. *International Journal of Technology and Design Education*, *23*(3), 489-517.

Hartell, E., & Skogh , I. (2015). Criteria for Success: a study of primary teachers´ assessment of e-portfolios. *Australasian Journal of Educational Technology*.

Ritchie, J., Lewis, J., Nicholls, C. M., & Ormston, R. (Eds.). (2013). *Qualitative research practice: A guide for social science students and researchers*. Sage.

Swedish National Agency for Education (2011). Ämne - Teknik, grundskolan [Syllabuses for compulsory school Technology]. Retrieved 2016-05-02 from http://www.skolverket.se/laroplaner-amnen-och kurser/grundskoleutbildning/grundskola/teknik

Williams, P. J., Iglesias, J., & Barak, M. (2008). Problem based learning: application to technology education in three countries. *International Journal of Technology and Design Education*, *18*(4), 319-335.

Student teachers' views and experiences on actualising technology education in practice

Eila Lindfors
University of Turku, Department of Teacher Education, Rauma Unit
Rauma, Finland
eila.lindfors@utu.fi

Abstract

The article presents a study on student teacher experiences and views after authentic workshops realized in a local school. The technology education theme day consisted of three different workshops related to electronics and automation in MecLab and OPT10 learning environments. The workshops were designed and organized by craft, design and technology student teachers in elementary school on 5th and 6th grades (11 and 12 years old pupils) as a part of their master studies and the INNOTEK-project. Learning environments were FESTO high tech automation learning environments which presupposed and taught electrical circuits, automation control and programming skills. The data is from semi-structured questionnaire with open-ended questions which student teachers (12 teams with 2-3 persons in each) answered as teams after the workshops. The data analysis is qualitative inductive category development content analysis. The main result is that experiential technology teaching and learning seems to support teachers' and pupils' motivation on technology education. Especially girls were very enthusiastic learners. The study gives an example on how to implement technology education in basic education as well as in teacher education. Even though the data is small the results are consistent with earlier research and give special hints on how to solve the problem of girls' negative attitudes towards technology and technology education.

Keywords: technological literacy, automation technology, programming, student teacher, basic education, experiential learning, authentic learning.

Introduction

Our 21st century everyday living environment is becoming more technological. One of the most important and fundamental human capital is knowledge of living with technology and using it in our everyday life. While use of automation and robotics will increase in society, technological literacy of citizens will be even more important in the future. Ability to identify technological problems, ability to search relevant and meaningful information to find possible solutions and ability to utilize the knowledge acquired in problem solving and assessing the solution are crucial in technological literacy (Ward, 2015). The expanding significance of technological literacy in society requires developing the learning opportunities of it (Jones, 2009; Ward, 2015). Authentic experiences in learning should support the development of technological literacy while learners should have opportunities to become familiar with such technological systems that are widely

used in the society (Luomalahti, 2004). In experiential learning an authentic experience is a source of learning and development (Kolb, 2015).

As a part of general education, technology education should promote innovative use of knowledge in circumstances where human needs and challenges will be solved by practical actions and the results can be evaluated in real use (Lindfors, 2007, 2010). However general education is criticized continuously for not promoting creativity, innovation and technology learning even the growing meaning of these in society (Bencze, 2010; Cropley & Cropley, 2010; Lindfors & Hilmola, 2015. The importance of this challenge is highlighted in the new Finnish National Core Curriculum 2014 for Basic Education (grades 1-9, 7-16 years old pupils) in Finland (FNBE, 2014) which will be deployed this year (2016). In the subject of craft, design and technology (CDT, Crafts) the focus is on developing students' exploratory, creative, active, and entrepreneurial future-oriented working. Hands-on learning on a wide range of materials and technological areas will be the main didactical guideline in promoting students' open-minded use and application of knowledge as well as their problem-solving skills (see Lepistö & Lindfors, 2015).

Science or technology concepts are often abstract and difficult to understand (Mulhall, McKittrick & Gunstone 2001). We know e. g. that students have difficulties to understand and evaluate technical solutions (Björkholm, 2014). However, analogies make them more understandable for pupils, helping them to make connections between everyday life and these concepts that are intended to be learned. By using analogies, teacher can help pupils create mental models that link new ideas to prior experiences. (Smith & Abel 2013). Executing technology learning in authentic learning contexts connected to pupils every day experiences supports pupils' creative problem solving instead of learning specific facts or skills (Lin & Williams 2015; Twyford & Järvinen 2000). Authentic learning context is a frame for a holistic understanding and promotes good learning results (Hill 1998; Hill & Smith 1998; Kolb 2015). Experiential learning gives opportunities to learn in hands-on working and in a quite short period of time it is possible to enjoy despite of the challenging content of learning (Pirttimaa, Husu & Metsärinne, 2015). However, girls' attitudes to technology learning is a constant concern (Lindfors, 2007; Shapiro & Williams 2012). E. g. in domestication of everyday technology in families men still have a leading role (Talsi 2014).

In this study student teachers designed learning tasks for pupils in order to promote technology education according to the new curriculum and practice. The purpose was to develop technology education implementation in basic education as well as in teacher education. The student teachers were encouraged to plan connections between things familiar for pupils and technology equipment in use. After the workshops the student teachers answered to a semi-structured questionnaire on the basis of their views and experiences.

Research design

Study Context and Participants
The study was carried out in CDT-teacher education program in Finland in Autumn in 2015. The student teachers (n=34) studied in the course KSS6.8 Everyday technology in phenomenal learning (4 ECTs CREDITs). The course is related to the INNOTEK 2015-2017 –Innovations from automation technology– research and development project that tries to respond to society's need for future oriented education e. g. technological skills and innovation learning. The project supports the implementation of the new National Core Curriculum for Basic Education (FNBE, 2014) concerning the aims of technology

education, especially programming, robotics and automation technology. The INNOTEK-project is funded by the Technology Industries of Finland Centennial Foundation. One research goal in the project is the usability evaluation of MecLab and OPT10 learning environments in school context.

As a part of the course the student teachers organised a theme day at elementary school with 3 various workshops on 5th and 6th grades (11 and 12 years old pupils) as a part of their master studies and INNOTEK-project. The theme day was a final part of the course and the goal was to put theory into practise and experience technology education in work life context. The learning environments were high tech automation learning environments MecLab (figure 1) and electronics learning environment OPT10 which taught electrical circuits, automation control and programming skills. The student teachers were unsure of their skills and knowledge to teach programming and automation after lectures on technology education and phenomenal learning, demonstrations and workshops of their own and the theoretical literature exam. They were also suspicious wheather pupils would be interested and motivated in learning with new learning environments. The research question is: What experiences and views student teachers had after hands-on teaching in technology education workshops?
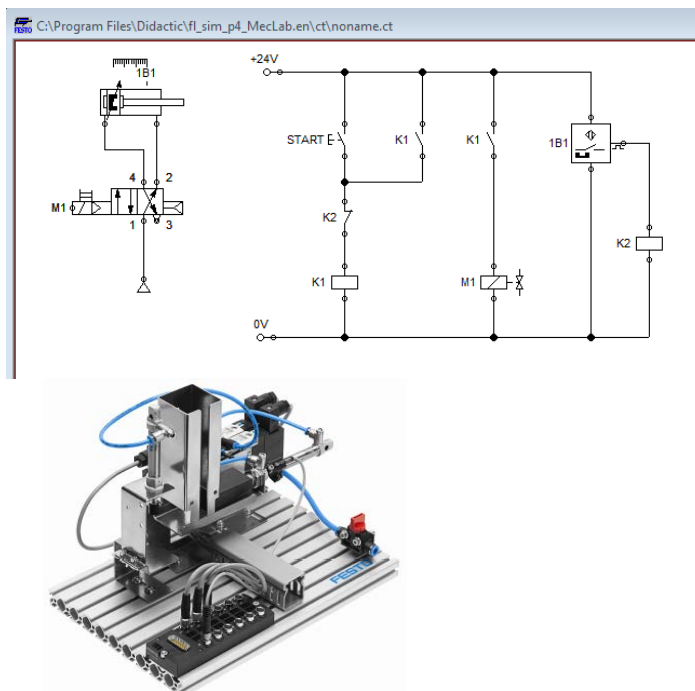
FIGURE1. FluidSIM program capture – pneumatic and electric circuit & MecLab stacking magazine station (Festo Didactic material 2015).

Student teachers designed simulation exercises for pupils to teach the basic idea of MecLab and OPT10 learning environments and creative problem solving tasks to promote creativity. The examples and the task contexts were driven from pupils' everyday life and interests: for example a bottle recycle automation system (obligatory in every super-market in Finland) and a candy factory automatic packing line. The pupils learned to use FluidSim program (figure 1) in order to program electric and pneumatic circuits and combine them with the real automation environment (MecLab). After learning the basics in simulation phase, the pupils proceeded quickly to problem solving and acted like engineers who design and program technological systems. They participated into three different workshops tutored by a group of two to three CDT student teachers: OPT10 – practising electrical circuits, programming MecLab stacking magazine station

(fundamentals of pneumatics) and programming conveyor station (detection and sorting of workpieces).

Data Collection and Analysis

The data is from reflective semi-structured questionnaire with open-ended questions, which student teachers (12 teams with 2-3 persons in each) filled in the end of theme day. The teams had practical experiences on hands-on technology education in three workshops, each lasting 90 minutes and having 8-12 pupils working in four groups.

The data analysis is qualitative. By using inductive category development content analysis the written reflections were reduced to essential expressions and reconceptualised to sub and main categories (Krippendorff, 2004). The task was to identify the central themes from the student teachers' experiences and views to be able to reintegrate similar themes to subcategories and upper categories that explain the student teachers' experiences and views as a whole and may promote discussion on how to develop technology education in a fresh way in basic education as well as in teacher education.

Results

The analysis revealed five main categories in student teachers experiences and views (table 1): 1) the enthusiasm of pupils encourages (student)teachers, 2) experiential learning environment and tasks encourage pupils on goal-oriented learning, 3) girls are very enthusiastic in learning technology in experiential learning environment, 4) the learning tasks combined with everyday technological solutions encourage pupils on applying their knowledge and skills creatively and 5) timely support and guidance is crucial in technology learning.

All the student teacher teams (n=12) expressed very clearly that they enjoyed working with pupils in workshops. They were surprised how eagerly pupils worked. Before the workshops they were anxious and unsure of themselves as teachers and their knowledge on automation and electronics. The enthusiasm of pupils encouraged and motivated student teachers.

The pupils worked in workshops actively and were very motivated despite of their earlier weak knowledge and skills in electronics and electricity. The student teachers were surprised how quick-learners the pupils were while they used FluidSim-program and programmed the stacking magazine and conveyer station as well as electric circuits with OPT10. Pupils wanted to get the systems functioning and were very goal-oriented.

Table 1. Student teachers experiences and views after experiential workshops.

Subcategories	Upper Categories	Main Category
Student teachers really enjoyed working in workshops with pupils	The enthusiasm of pupils encourage and motivate student teachers	Experiential technology teaching and learning supports teachers' and pupils' motivation on technology education
Pupils were very enthusiastic while working in the workshops		
Pupils focused on goal-oriented learning	Experiential learning environment and tasks encourage pupils on goal-oriented learning	
Pupils' weak knowledge on electronics and electricity		
Pupils learned electronics in experiential learning environment surprisingly quickly		
Pupils were motivated on learning		
Girls enthusiasm to technology learning was surprisingly high	Girls are very enthusiastic on learning technology in experiential learning environment	
Some girls needed encouraging and support in technology learning even they succeeded in tasks		
Girls learnt very quickly applicate their knowledge		
Pupils were eager to make programming and construction applications of their own	The learning tasks combined with everyday technological solutions encourage pupils on applying their knowledge and skills creatively	
Pupils' learning was combined on everyday technology applications		
Pupils need for support and guidance in programming	Timely support and guidance is crucial in technology learning	
Group work of pupils support in full-filling the tasks		

A usual concern in technology education is girls' attitude and motivation to technology. In these workshops the student teachers experienced girls being enthusiastic. This was mentioned by most of the teams. They also mentioned that girls learnt quickly and could apply knowledge and make their own solutions in programming. However some girls needed encouraging to know that they were doing right. As a whole it seemed that the girls are very enthusiastic on learning technology in experiential learning environment where they could immediately see how their operations effected to the stacking magazine and the conveyer station and the OPT10 electric circuits.

Every task student teachers gave to pupils had a story. Weather it was some factory automation production example, the bottle recycle machine or automatic golf putt - it was somehow 'touchable' and pupils were surprisingly eager to start working. The best phase was when the pupils saw their system functioning after drawn the electrical and pneumatics circuit diagrams and connected these to the stations. After that pupils could start making creative solutions by programming the system in new ways. Based on student teachers experiences the learning tasks combined with everyday technological solutions seem to encourage pupils in applying their knowledge and skills creatively. In that the pupils needed timely support and guidance which they got from student teachers and from each other. On the basis of analysis it seems that experiential

technology teaching and learning supports teachers' and pupils' motivation on technology education.

Conclusions

The experiences and views of student teachers were surprisingly positive. The pupils' feelings about the workshops were very positive. They worked with enthusiasm, and teacher students were very surprised about their positive attitudes towards the learned contents, especially the interest of girls. The MecLab and OPT10 learning environments proved to inspire pupils at school context. Related to the concern on girls' attitudes to technology the girls proved to be eager and quick learners on the basis of student teachers experiences (table 1). Part of the pupils' enthusiasm in the workshops could be the attractiveness of the new learning environments. They also got support and guidance when needed because the amount of pupils (8-12) per (2-3) student teachers was reasonable. On the other hand, after getting more experience with challenging teaching content it is possible to have more pupils under guidance of one teacher. It seems that integrating theory to practical examples and applications in workshops with pupils encourages student teachers and gives them self-confidence in acting as teachers. It seems that experiential teaching and learning creates a positive circle in which the pupils' motivation on technology education supports and encourages student teachers in teaching and tutoring in the workshops. There is no doubt that authentic everyday examples and learning environment support good learning results (Hill 1998; Hill & Smith 1998; Kolb 2015) even though the content of learning would be demanding (Pirttimaa et. al. 2015). The context of this study offer examples for teachers and schools how to develop technology education and in that way promotes the new curriculum (FNBE 2014) implementation.

From the teacher education's point of view the theme day with workshops was successful. It challenged student teachers, it gave positive and authentic technology learning experiences to quite young pupils at the local school. At the same it convinced teacher educators that student teachers should be supported to work in authentic learning environments with pupils as soon as possible even though they would be insecure with the content knowledge. Offering student teachers real opportunities to be able to combine theoretical knowledge and skills to practical working with pupils predicts the alterations of implementing technology education in more future-oriented way (see Lin & Williams 2015). The positive experiences with pupils encouraged the student teachers to develop their competence. We can conclude that working in workshops with pupils developed pupils' technological literacy (Ward, 2015) in the form of programming and automation technology as well as student teachers technological literacy and methods of promoting it.

Literature:
Bencze, J. (2010). Promoting student-led science and technology projects in elementary teacher education: entry into core pedagogical practices through technological design. *International Journal of Technology & Design Education, 20(1),* 43–62.
Björkholm, E. (2014). Exploring the capability of evaluating technical solutions: a collaborative study into the primary technology classroom. *International Journal of Technology & Design Education, 24(1),* 1–18.

Cropley, D. & Cropley, A. 2010. Recognizing and fostering creativity in technological design education. *International Journal of Technology & Design Education, 20(3),* 345–358.

FNBE. (2014). *National Core Curriculum for Basic Education* 2014. The Finnish National Board of Education. Retrieved from www.oph.fi/ops/perusopetus/pops_web.pdf

Hill, A. M. (1998). Problem solving in real-life contexts: An alternative for design in technology education*. International Journal of Technology and Design Education,* 8(3), 203–220.

Hill, A. M., & Smith, H. A. (1998). Practice meets theory in technological education: A case of authentic learning in the high school setting. *Journal of Technology Education,* 9(2), 29-41.

ITEA 2007. *Standards for Technological Literacy: Content for the Study of Technology.* International Technology Education Association ITEA 2007. Technology for all Americans project.

Jones, A. (2009). Looking back to look forward: The future of technology education. In A. Jones & M. de Vries (Eds.) *International handbook of research and development in technology education*. Rotterdam: Sense Publications, 407–417.

Krippendorff, K. (2004). *Content analysis: An introduction to its methodology*. 2nd ed. Thousand Oaks, CA: Sage.

Lepistö, J. & Lindfors, E. (2015). From Gender-segregated Subjects to Multi-material Craft – Student Craft Teachers' views on the future of the Craft Subject. FORMakademisk 8(3), art 4, 1-20. https://journals.hioa.no/index.php/formakademisk/article/view/1313/1440

Lin, K.-Y. & Williams, J. (2015) Two-stage hands-on technology activity to develop preservice teachers' competency in applying science and mathematics concepts. *International Journal of Technology and Design Education*. Online first. DOI 10.1007/s10798-015-9340-1

Lindfors, E. (2007). Technology Education: Will it be equally available to girls and boys in the future? In S. Karkulehto & K. Laine (Eds.), *Call for Creative Futures.* Publications of the Department of Arts Studies and Anthropology, A:15, 110–123. http://www.cream.oulu.fi/documents/ccf_ebook1.pdf

Lindfors, E. & Hilmola, A. (2015). Innovation learning in comprehensive education? *International Journal of Technology and Design Education*. Online first. DOI: 10.1007/s10798-015-9311-6.

Luomalahti, M. (2005). Naisopiskelijoiden teknologiasuuntautuminen luokanopettajankoulutuksessa [Female students' technological orientation in class teacher education]. *Acta Electronica Universitatis Tamperensis, 41*. http://tampub.uta.fi/bitstream/handle/10024/67465/95144-6238-6.pdf?sequence=1

McCormick, R. (2004) Issues of Learning and Knowledge in Technology Education. *International Journal of Technology and Design Education* 14(1), 21–44.

Mulhall, P., McKittrick, B. & Gunstone, R. (2001). A Perspective on the Resolution of Confusions in the Teaching of Electricity. *Research in Science Education*. (31), 575–587.

Pirttimaa, M., Husu, J. & Metsärinne, M. (2015) Uncovering procedural knowledge in craft, design, and technology education: a case of hands-on activities in electronics. *International Journal of Technology and Design Education. DOI 10.1007/s10798-015-9345-9.*

Shapiro, J. R. & Williams, A. M. (2012). The role of stereotype threats in undermining girls' and women's performance and interest in stem fields. 66(3), 175–183.

Talsi, N. 2014. *Kodin koneet. Teknologioiden kotouttaminen, käyttö ja* vastustus [Mundane Machines: Domesticating, Using and Opposing Technologies]. Publications of the University of Eastern Finland. Dissertations in Social Sciences and Business Studies. No 75. http://epublications.uef.fi/pub/urn_isbn_978-952-61-1376-0/urn_isbn_978-952-61-1376-0.pdf

Twyford, J. & Järvinen, E.-M. (2000). The Formation of Children's Technological Concepts: A Study of What it Means To Do Technology from a Child's Perspective. *Journal of Technology Education* 12(1), 32-48.

Ward, B. (2015) Deconstructing technological literacy: opening a Window to problem solving. Technology and Engineering Teacher 74(5), 18 – 22.

Skills training through hands-on practical activities in civil technology - a case study of three technical schools in the Eastern Cape Province, South Africa

M Makgato & M A Maeko
Department of Technology and Vocational Educational
Tshwane University of technology
South Africa
makgatom@tut.ac.za

Abstract

Skills' training for Civil Technology learners in South African schools is an aspect entrenched in the Civil Technology policy document in order to produce skilled personnel for sustainable economy. Practical activities through PAT (Practical Assessment Task) are national requirements for all practical –based subjects from Grade 10-12 in South African schools. The purpose of this study was to investigate the status of Civil Technology practical activities in three South African schools in the Eastern Cape Province. Purposive sampling was used to identify 41 leaners and 3 teachers to participate in the study. Questionnaires, semi-structured interviews and observation as data collection methods were instruments used to collect data. The study found that that learners exit Grade 12 without basic practical hands-on skills. Civil Technology practical activities were found to be not properly offered in the three schools investigated. Educators should be well trained by Higher education institutions to conduct practical activities with learners to equip them with marketable skills for sustainable economy after grade 12. Technology teacher education and training should include regular exposure and visit to related industry in order to keep abreast with the latest technological development. The supply of equipment to schools should be coupled with routine maintenance of the equipment.

Keywords: Practical skills acquisition, Civil Technology, Skills training, Eastern Cape, Practical activities
Discipline: Technology education

Introduction

Post-apartheid South Africa provided the Education Ministry with the opportunity to change the curriculum and one of the new subjects conceived for secondary schools, is Civil Technology which was previously known as Woodworking. Woodworking fell within Technical Education currently called Technology Education and had trades like plumbing, bricklaying and plastering taught separately. Learners, who studied the subject, would go for apprenticeship, get a trade test certificate, become artisans and entrepreneurs and earn a living if they are not willing to further their studies. Apprentices normally do a trade test at the end of their training at the Institute for the Development of Learnerships and Learnership Assessment (INDLELA), after which they will be certified, if successful and be recognized as artisans within the relevant industries (Department of Labour, 1998). The Civil Technology subject is designed to provide learners with a sound technical base that integrates both theory and practical competencies (DoE, 2005). According to the curriculum assessment policy statement (CAPS) (DBE, 2011) learners who study Civil Technology Grade 10-12 will acquire skills which will make it easy for them to enter into Learnerships or Apprenticeships that will prepare them for a trade test. The CAPS (DBE,

2011) list among other things the workshop with tools and equipment together with measuring equipment and consumable items as the basic requirements to achieve this objective. Kennedy (2011) states that since the Civil Technology course is intended to be practically oriented, less theory should be taught. The purpose of this study was to investigate the status of Civil Technology practical activities in three South African schools in the Eastern Cape Province.

Civil technology in schools

The school system, through technical schools and through technology education subjects in academic schools has been contributing to skill development (McGrath, 1998). Leaners in South African schools only start doing Civil Technology from Grade 10 up until Grade 12 and that is where the practical component is also supposed to be implemented. According to policy document (DBE, 2011) Civil Technology subject is allocated 4 hours in schools of which 2½ hours are for teaching theory and 1½ hours meant for the practical lessons on a weekly basis. According to Brunette (2006), technology subjects must have practical work, as applying theory in practice provides the practical experience that is necessary. In the study Brunnete sadly discovered that schools produce many learners without technical skills. Technology education is viewed as education, which equips learners with marketable skills after grade 12 for sustainable economy. In other countries such as Canada, technical skills training was meant to enhance the general education of students intending to join the labour force on leaving school. It offered industrial skills for youth who had completed high school and occupational skills for adults (Gardner and Hill, 1999). The traditional pedagogy of workshop-type technical subjects was, and still in many cases, 'demonstration and follow' (Fritz, 1996), and it has been used to good effect in the developing of student competencies, particularly in industrial skills. However, technology education's evolution is transforming the subject from one that requires learners to imitate teacher-prescribed industrial hand and machine skills to one that is argued to be unique in the school curriculum (Walmsley, 2003). Technology education is developed to become a subject that is aimed at promoting an individual learner' ability to solve real world problems by integrating specifically relevant knowledge of structures, materials, technological process and systems (Department of education, 2003).

Technology education is considered to be the panacea for the country's economic development and prosperity. Majority of learners in South African schools are characterized by a lack of exposure to technological products (e.g mechanical toys) and hence lack experiences in 'Do It Yourself' (DIY) tools (Martin, Dakers, Duvernet, Kipperman, Kumar, Siu, Thorsteinsson,. & Welch, 2003 & Makgato, 2011). According to Galluzo, (1996) there is no faith in the ability of teachers and the present schools to produce students who will excel at the industrial job market . The loss of confidence is fuelled by the beliefs that a) the present configuration of schools is incapable of producing youths who can meet the increasingly complex demands of the workplaces and, b) present school curriculum is outdated (Department of Education, 2000). As Frantz put it, all students who graduate from high schools should acquire sustainable economic skills needed for employment as well as those required to continue their education (Makgato, 2011). The quality of technology education programmes is greatly determined by the successful students having acquired the skills for economical development , knowledge and values needed by society (Makgato,2011). The educational system is not preparing children for a career after school, but merely to matriculate. School education is geared at making children job seekers and not job providers. In order to prepare job-providers in the country, the education system should make a significant paradigm shift by emphasizing hands-on technological skills that can sustain our economy at all school levels (Makgato,2011). The situation at schools in South

Africa still requires much attention concerning equipping students with sustainable economic skills through quality technology education. Technology subjects are designed to respond to societal changes, such as those evident in many of world's current post-industrial technological societies (Lauda,1988).

Designing and Making in technology education will make learners technological literate. Learners will become more innovative, knowledgeable, skillful, adaptable and enterprising. This will enable learners to:

- Respond critically and resourcefully to challenges
- Devise creative ways of generating and applying ideas
- Translate ideas into worthwhile outcomes
- Find innovative solutions to community needs
- Focus on the design of techniques and products
- Deal with uncertainty in an informed way
- Cooperate in flexible teams
- Appreciate cultural differences
- Learn throughout their lives
- Use local, national, regional, and international networks (Rasinen, 2003).

The technological design process involves the application of knowledge to new situation, resulting in the development of new knowledge. Technological design requires an understanding of the use of resources and engages a variety of mental strategies, such as problem solving, visual imagery, and reasoning. Developing these mental abilities and strategies so that they can be applied to problems is a significant aspect of technological literary. These abilities can be developed in learners through experiences in designing, modeling, testing, troubleshooting, observing, analyzing, and investigating (Walmsley, 2003). These types of skills provide learners with the opportunity and facility to fulfill the various requirements of the technological design process.

Bjurulf & Kirlbrink (2012) pointed out that to infuse theory into practical, teaching and learning is expected to take place in the different learning arenas e.g. schools and workplaces. In schools, the workplaces can be referred to as practical laboratories or workshops. Bjurulf & Kirlbrink opined that if schools cannot afford expensive machines, they may enter into partnerships with industries to teach specific course components at a workplace environment. Nze & Ginestie (2011) discovered that the absence of equipment incites technology teachers to replace practical classes with ones of theoretical nature. They further on affirm that equipment and its usage is an attribute for technology education.

A meeting of the Bureau of the Conference of Ministers of Education of the African Union (COMEDAF II, 2007) reports that offering technology education practical in schools is unlikely to be effective when delivered concurrently with general education subjects. This is because the practical component of technology education requires the material and time which is too expensive to provide in all schools. Further, the report explains that in general, the quality of training in Africa is low, with undue emphasis on theory and certification rather than on skills acquisition and proficiency testing.

Workshop equipment and materials for practical activities in civil technology

Civil Technology is a practical subject and according to Rosa & Feisel (2005) applying skill to everyday life requires both theory and hands-on workshop. While the former lends itself to classroom learning, the latter can only be learned and practiced in the workshop. Working with materials and tools should lead to the development of manual skills, cognitive reasoning and the transference of these abilities to what has been designed in reality (Seiter, 2009). School workshops offer opportunities for practical training of students in skill acquisition in their technology education areas for future development of

the key sectors of the economy in order to meet the basic needs of electricity, roads and machinery, among others (Umar & Ma'aji, 2010).

However, Mwaokolo (2003) affirms that the training received by learners in technology education, workshop in particular, is quite different from what they meet afterwards. In schools, the emphasis on skills acquisition which is the hallmark of technology education is an illusion. In the study, Mwaokolo maintains that most schools in Nigeria do not have workshops for practical lessons. There is no longer much emphasis on the learner's practical skills acquisition.

The Windhoek Technical High School threatened to close down its workshops due to the lack of materials and old equipment that not only hampered practical work, but increased the safety risk (Van Zyl, in Brunnete 2006). This is in contrast to the findings by Simiyu (2009),that in Kenya there is ample wood workshop space for practical lessons and that the machines are adequate for the number of learners studying civil technology subjects and that the maintenance of equipment and machines is elaborate. Umar & Ma'aji, (2010) assert that the availability of appropriate facilities enhances student learning by allowing them to be involved in demonstrations, and practice will continue to build their skills.

To worsen the situation, Puyate (2002) maintained that the present state of technology education facilities is very poor, there is no planned means of maintenance of the already broken down equipment or means of purchasing new ones, there is little or no concern on the part of government, teachers and students for the improvement of the present state of facilities. Anyakoha (1992) noted that the development of useful skills can be reinforced by the appropriate selection and use of learning facilities and resources. These facilities comprises of workshop structures, working materials, teaching materials, workshop tools and equipment. In the same vein Uzoagulu (1992), warned that where equipment and tools are not functional or adequately provided, technology training programs will suffer and will lead to the production of highly unskilled personnel who are unemployable and unproductive.

Letsie (2003), in his contribution from a South African perspective points out that as much as technology subjects offer an array of vocationally focused subjects with a practical orientation, most South African schools depend on theoretical studies with little access to technological facilities linked to apprenticeship. Skills development in the South African context has gone through many changes over the last decade, and the skills development gap is still broad. South Africa is expected to be active global player and tackle the burden of unemployment and poverty (Steinaker-Key, 2014). Technical high schools or comprehensive schools are expected to contribute to skills development through practical-hands on practical vocational and technical education. So far, it is not very clear to what extent are technological practical subjects at schools in South Africa produce skilled youth employable at various industries. Based on the critical needs for skills development and advocacy to train skilled youth, it was important to investigate the state of practical activities in technological subjects such as Civil technology in some schools in Eastern Cape Province.

Research Questions
This study were guided by the following research questions
1. How often do Civil Technology teachers teach practical (if any) in schools?
2. What is the state of practical workshops in schools?
3. How are practical tasks and theory taught in the classroom?

Theoretical framework

      (a) The theoretical framework for the study was based on David Kolb's Learning Styles Inventory (KLSI) model and Experiential Learning Theory (ELT) as defined by Kolb (1979, 1984). Experiential Learning Theory provides a holistic model of the learning process and a multilinear model of adult development, both of which are consistent with what we know about how people learn, grow, and develop (Kolb, Boyatzis and Mainemelis, 1999).Though Kolb's proponents view his model as too mechanistic and lacking in strong empirical validation, this study, however view it as relevant as it is aimed at capturing the nature of learning through action. Thus the theoretical frame work chosen for this study is relevant because the study is based on the integration of theory to practical knowledge of the Civil Technology subject. Kolb's learning theory sets out four distinct learning styles, which are based on a four-stage learning cycle (which might also be interpreted as a 'training cycle'). The four stage learning cycle consist of (1) Concrete Experience (CE); (2) Reflective observation (RO); (3)Abstract Conceptualization (AC) and (4)Active Experimentation (AE). Concrete Experience is when the learners active participation in the Civil Technology practical workshop is occurring, i.e learners first see the project they are supposed to do in the workshop. Reflective Observation is the stage when learners reproduce their own explanations from the drawing. Johnstone and Al-Shuaili (2001) are of the opinion that a student struggling to operate a piece of equipment may have failed to make important observations. Abstract Conceptualisation is when the students conceptualize the principle relating to how the final product would look like from the drawing. Active Experimentation is a doing stage, where learners are expected to manipulate equipment, materials and tools taking safety issues into consideration. In relation to this study, Kolb's four learning styles involve the process which leads learners to understand, design and make the final practical model in the workshop. To be able to do this, learners are expected to conceptualize and put the project to be made, in either drawing form or most importantly to be able to interpret the project drawn on paper.

Methodology

Purposive sampling was used to identify 41 learners and three teachers to take part in the study. Data was collected through questionnaires for learners, interviews for teachers and the researcher's observation in the classroom which was adapted from the differentiated classroom observation scale protocol instrument derived from the study by Grant, Stronge & Popp (2008). According to Merriam (1998), judgmental sampling technique is a sampling which looks for people who can provide the required information to respond to the critical question of the study.

All learners and educators involved with civil technology subject in all three schools were respondents. Questionnaire data was analyzed using the SPSS statistical software. The analysis of results was in the form of frequency distribution. Interview data was first analyzed by transcribing. Each transcription was considered with the aim of identifying and underlining key issues. Descriptions were then formulated from the key issues identified as relevant to the study and coded. Themes were created and categorized into headings and narrated with the support of verbatim, while observation data was analyzed descriptively per item as reflected in the schedule. Each item on the observation

schedule was analyzed per school with the purpose of getting a connection of the activities in the Civil Technology workshops in the three schools.

Results and discussions

The results of the study were presented in terms of three categories namely, questionnaire, Interview and Observation data

The overall questionnaire responses from the learners

Barriers to the teaching and learning of Civil Technology practical activities were listed on the table below where respondents answered as follows: Strongly Agree-SA, Agree- A, Disagree –D and Strongly Disagree –SD. Learners were requested to tick which they agree or disagree with from the table.

Table 1: Workshop resources and skills acquisition as viewed by learners.

	PERCENTAGES %			
Workshop resources and skills acquisition	**SA (1)**	**A (2)**	**D (3)**	**SD (4)**
No enough tools in the workshop	22 (54)	16(39)	1(2)	2(5)
The tools we have are no longer in good condition.	18(44)	15(37)	2(5)	6(15)
We do not have materials for practicals in the workshop.	11(27)	19(46)	3(7)	8(20)
There is no machinery in the workshop	20(49)	10(24)	3(7)	8(20)
We do not have access to the usage of machinery(if any) in the workshop for practical projects	25(61)	4(10)	1(2)	11(27)
We often prepare materia(if any) on our own for the project	13(32)	3(7)	15(37)	10(24)
We do not do practicals weekly in the workshop	33(81)	6(15)	1(2)	1(2)
There is more time allocated for practical lessons weekly in the timetable	2(5)		9(22)	30(73)

Table 1 above indicates that the majority of the learners (83%) agree that the tools they have in the workshop are not enough and they have to share. Most (81%) of the learners also agree that many of the tools they have are not in a good condition. From the table, 73% of the learners agree that materials and machinery respectively are short of supply in their practical workshops. Puyate (2002) also found that the present state of technology education facilities is very poor, there is no planned means of maintenance of the already broken down equipment or means of purchasing new ones. Puyate argues that there is little or no concern on the part of government, teachers and students for the improvement of the present state of facilities. When asked if they access to the usage of machinery in the workshop for their practical projects, 71% of the learners agreed that they do not prepare the material on their own but teachers do that for them. The respondents (86%) also agreed that they do not conduct practicals weekly in the workshop whiles, 95% complained that the time they spent in the practical workshop is just too little. According to Brunette (2006), technology subjects must have practical

work, as applying theory in practice provides the practical experience required by workforce. This implies that learners leave grade 12 without adequate or practical hand-on skills. Brunnete (2006) also discovered that schools produce many learners without technical skills. The results indicate that learners are not doing the practical lessons as prescribed by the Civil Technology policy which advocates 1½ hours of time which is supposed to be spent by learners weekly in the workshop for practical lessons.

Interview results responses

The analysis of interview data are presented and discussed in terms of the themes below, of which the first two themes tend to respond to research question 1 and 2.

The importance of workshop practicals for learners doing Civil Technology as a subject

The Civil Technology teachers consistently acknowledged the importance of workshop practicals for learners doing Civil Technology, as it is an integral part of the subject. The respondents unanimously indicated that the practical component of the subject help learners understand the theory part of the subject. One theme that consistently emerged when the teachers responded to the issue of workshop practicals is that it is of extremely importance for learners to do practicals.

The respondents are of the view that learners should be able to become self-employed and create jobs on completion of their Grade 12 without any further training. However, teachers felt that the current training of learners does not offer them such opportunities.

The subject teacher from school A stated that the practical component covers a lot because it can train the learners to become self-employed, and also to give the learners an opportunity for employment after Grade 12 in case of them not willing to further their studies. The subject teacher said

"for learners to make sense of the theory part, they have to go to the practical workshop to put what they have just learned into practice. Some of the learners who went through my hands at the school during the apartheid era are self-employed and make a living without any further training". This is reminiscent of Uwameiye's (1993:17) assertion that the practical work constitutes an essential component of technology education.

Challenges for teaching the practical component

The study used interviews on three Civil Technology teachers to determine the state of practical activities, in terms of teaching and learning in a practical workshop. This theme respond to research question two to understand the state of practical workshop at the schools. All the three Civil Technology teachers from the three schools agreed that teaching the Civil Technology practical component is a laborious task. The teachers said that the challenges they face with regard to the practical component seems to have no solution.

Teacher C from School C was recorded saying. *"Training material is a challenge; the government doesn't supply us with the material. Tools are expensive, machinery is old and to replace the machinery with the new is expensive. We end up levying the parents for us to be able to buy material for learners to be able to do practical. Generally the practical cover only what we have in terms of equipment which should not be the case as far as the syllabus and skills acquisition is concerned".*

Then Teacher A from School A said. *"We teach theory without the practical because we lack material and equipment. We do not even have a proper workshop for the practical lessons and this compromise the quality of what we are offering to learners in Civil Technology".*

In response to the question of the state of practical workshop for Civil technology the teacher from School B said:

"The challenges we have concern the shortage of equipment and material as the government does not supply us with these materials and equipment. Although the government officials emphasize the importance of the practical skills when addressing the media, the reality is that we are practically suffering in schools. As a result, we are also lacking

behind with the use of the latest modern technology equipment with regard to the practical component as no one from the government is concerned about the practical component of this subject. This happens despite the fact that technology changes all the time which necessitate that there be further training to keep abreast with technological developments".

Time for starting with the practical project for Grade 12 class

This theme tend to respond to research question one which wanted to know the rate of conducting practical activities in the classroom at the schools. Teachers stated that the practical was supposed to start earlier at the beginning of the year to give learners more time to practice skills. Teacher C said the following "*We were supposed to start at the beginning of the year to equip learners with practical skills, but because of the lack of material we do projects in the fourth quarter when moderation is about to take place just to meet the Civil Technology curriculum requirements for PAT as opposed to skill acquisition. We rush the practical so that learners to get the 25% of the PAT. We are sent from pillar to post when we knock on provincial government doors asking about material and equipment for learners".*

However the teacher B from School B had this to say: *"The learners only get a chance to go to the practical workshop in September to prepare for PAT. Unfortunately this is the only time the school buy us material for the practical component".* The findings from the interviews with teachers indicate that the three schools are only interested with learners receiving the practical mark as opposed to the practical skills.

The sentiments expressed by these teachers above echo the findings of Okorie's (2001) study about the dearth of tools in the school's technology education workshops and that the few that were available were obsolete, non- functional and could not meet the curriculum requirements. Uwameiye's (1993) emphasis that practical work constitutes an essential component of technology education. It is further argued that without suitable workshop spaces, classrooms and laboratories, programme implementation and structuring would be very difficult if not impossible (ibid). However, this is in contrast to the findings by Simiyu (2009) that in Kenya there is ample wood workshop space for practical lessons and that the machines are adequate for the number of learners studying Civil Technology subjects and that the maintenance of equipment and machines is elaborate.

Learners' readiness to be entrepreneurs or work in industries after Grade 12

Teachers were asked whether learners acquired sufficient hands-on practical skills that meet the needs of technological industries, and it emerged that the pattern of responds are similar. Most of the respondents expressed the view that learners will not have acquired proper skills to become entrepreneurs or even work in industries after Grade 12.

According to Osuala (2004) the shortage of equipment and materials of technology education equipment impedes the training of the students and that they end up not acquiring enough skills to go into the labour market. Teacher A from School A had this to say:

"Our learners cannot get the skills to become entrepreneurs upon completion of their Grade 12 because the training they get is not up to scratch. They are not getting the kind of skills which will make them become entrepreneurs after completion of their Grade 12.The learners can only get the skills required for them to become entrepreneurs if they get further training. The advantage is that the learners stand a good chance to do Civil Engineering at Higher Education Institutions because of the built background they are exposed to. In the NCS learners do projects with cardboards and not with real material like in the old system. So this disadvantages them from dealing with what they should expect in reality".

Similarly, the teacher from School B said that the lack of material and equipment make skills acquisition impossible as the time the learners spent in the workshop is too little to enable them to acquire the skills they need given the fact that the school time table does not even accommodate the practical lessons.

Observation results

Non-participatory observations was done in the classroom of the three schools involved to answer all the RQs stated in the study. The observation schedule was underpinned by literature discussed as well the Kolb's Experiential Learning Theory (Kennedy, 2008; Gamble, 2003; Umar & Ma'aji, 2010; Kolb ,1999). In particular, the observation sought to investigate the state of practical workshops in schools and the teaching and learning of practical tasks, i.e the integration of theory and practice in Civil technology classrooms.

Arrangements were made earlier with both the Head of Departments and Principals in all the sample schools to conduct the observation. The observation data were analysed according to themes as presented and discussed below.

Student's ability to use machinery

On the learners' participation in the use of machinery, the researcher observed that the majority of the learners are unable to use the available machinery in the workshop. The researcher also established that the majority of learners do not have access to most machinery in all the three selected schools. This is attested to by Kennedy's (2008) argument that facilities like classrooms, workshops, laboratories, studios, equipment and materials are grossly inadequate in secondary schools.

State of the workshop

The findings from the researcher's observation reveal that the state of workshops in all the three sampled schools is poor. This observation confirms the responses of the majority of the learners and the teacher's responses that the workshops in the three sampled schools are in a poor condition. Most of the machinery is broken and therefore remain dysfunctional. This is anchored and corroborated by Puyate's (2002) argument that the present state of technology education facilities is very poor as there are no planned means of maintaining the already broken equipment or means of purchasing new ones and there is little or no concern on the part of the government, teachers and learners for the improvement of the present state of facilities.

Correct handling of tools

Tools can be dangerous if not properly handled. They can cause serious injuries and even death because most of them are sharp. Few leaners in all the sampled schools were seen to be handling tools properly as the majority of the learners were not following the correct procedures of handling tools.

Though most of the tools were not in a good condition the handling procedure is critical for safety reasons. According to the Department of Education in Papua New Guinea (DoE PNG) (2006) the skills to be taught and learnt in the practical workshop are inclusive of responsible and safe use of a range of tools, materials and techniques in the workshop.

Availability of equipment and material

Notably, in all the workshops in school A, B and C respectively, the availability of equipment and material is a problem. The finding from the researcher's observation is that in all the three selected schools materials like timber and safety gear is a big challenge.

Personal Protective Equipment (PPE's) like safety goggles to protect the learners' and teachers' eyes from flying wood chips, dust masks to prevent inhaling of dust which might cause lung diseases, ear-drums to protect ears from getting damaged by excessive noise coming from running machinery, safety gloves to protect hands from cuts and safety clothes like boots and overalls, are short in supply. As argued by National Union of Teachers (2011), for every kind of practical activity teachers should give priority to

ensuring the availability and use of protective equipment and safety should be a priority for teachers supervising practical activities.

Personal protective equipment (PPE's) can be described as the equipment worn from head to feet, in order to protect workers from injuries and contracting diseases in the workshop. Anyakoha (1992) argue that the development of useful skills can be reinforced by the appropriate selection and use of learning facilities and resources. These facilities, according to Anyakoha, comprise workshop structures, working materials, teaching materials, workshop tools and equipment.

The teacher's demonstration on machinery

For skills to be transferred, it is important that teachers demonstrate to the learners what needs to be done with the machinery. All the teachers from the selected schools demonstrated a high level of knowledge on the available machinery. However, the teacher from school B was seen operating machinery without PPE's. Instead of using the mask to protect him from inhaling dust, the teacher was observed to have inserted tissues in his nostrils. Though all the teachers did not follow safety and health measures, they knew how to use the available equipment. This contrast with Apagu & Andural's (2007) assertion that school teachers lack the knowledge and skills in the handicrafts subject because the curriculum used in preparing those teachers lack these aspects of education.

Umar & Ma'aji, (2010) assert that the availability of appropriate facilities enhances student learning by allowing them to be involved in demonstrations, and practice continues to build their skills. However, most of the technical colleges in Nigeria have been forced to perform below standard due to purported non availability, poor management or utter neglect of the required facilities in the workshops for effective training.

Status of equipment (tools and machinery)

This aspect was relevant to help check the status of the available equipment in workshops in the sampled schools. With this aspect the researcher established that some of the machinery is either in a poor condition if not broken and unused. This confirms the responses of the learners in table 1.4 and 1.6 where 80, 5% and 73.2% of the learners respectively agreed that tools and machinery are not in good condition.

Safety procedures

The workshop can be a dangerous place to work in as it contains sharp objects and dangerous machinery. With regard to this variable, the researcher observed that in all the sample schools, safety is only considered when operating machinery together with the handling of tools. This then leaves both teachers and learners exposed to health hazards. In all the selected schools learners together with their teachers were seen to be working without Personal Protective Equipment.

Leaners together with teachers were observed to be working in dust and noisy environment caused by machinery without PPE's. Notably, woodworking exposes workers to a variety of hazards, including kickbacks, flying wood chips, noise, wood dust and chemical hazards. Personal Protective Equipment can help protect against these hazards (National Union of Teachers, 2011).

Infusion of theory with practice

On this aspect, the researcher observed that because of the lack of material and equipment, integrating theory to practical is a challenge. Learners in all the three sample schools only go to the workshop around September for one month for the practical project. Though at that time they would have learnt lot of theory but it becomes impossible to fuse it at once into practical in just one month.

The findings from this observation are corroborated by Bhurulf and Kilkbrink's (2012) argument that in bridging the gap between theory and practice, learners need to be taught theory or basic knowledge first before they can do practical lessons. It is argued

that this will help them to transfer knowledge learned to practice. On the contrary, Mjelde (1995) argues that a good approach in relating theory to workshop learning in the present educational reform is that theory and practice should be learned at the same time.

Conclusion and recommendations

The questionnaires, interviews and observations from the three schools as discussed above have revealed that all the workshops lack equipment and material to equip learners with technological skills for sustainable economy. The supply of tools in schools is a shame as most of the workshops in schools were found to be lacking tools, or having tools which are not in good condition to safely work with. It was found that most schools do not have workshops for practical lessons and that there is no longer much emphasis on the learner's practical skills acquisition for sustainable economy. The emphasis on skills acquisition which is the hallmark for sustainable economy is in terrible state. All the schools in the study were found to be not having a technician to fix broken machinery and that means any broken machinery is put aside to gather dust .The other common factor which can be described as a big challenge is the teaching of the theory most of the time because of lack of materials as mentioned. Because of the lack of equipment and material for practical lessons, learners spent most of the time in theory class therefore compromising the practical acquisition of skills. However, it has been found in other studies (Makgato & Mji, 2006) that delivering of equipment and materials at schools does not guarantee that practical activities in class will be done.

The findings also revealed that in situation where there is machinery in the workshop leaners do not have any access to the usage of such machinery. It could be that educators also do not appropriate skills to use the machinery, and they deemed it dangerous for the machines to be used by the learners. This practice of not allowing leaners to handle can be attributed to lack of proper professional training by educators. In all the three schools the study discovered that educators do the actual work for learners. This can also be caused by the fact that both educators and learners were pressed against time and rushing to complete the Practical Assessment Task project for moderation by the Department of Basic Education officials. This is a blow to skills development on the side of the learners, because the focus is on attaining marks for PAT than skills acquisition. This denies learners opportunity to get involved in their project from the foundation stages and therefore denying them a chance to manipulate tools and equipment to acquire skills for sustainable economy.   The late arrival of material was also found to be a contributing factor for failure by teachers to infuse the practical and theoretical component of the subject because of time constrains. Though both the educators and the learners are aware of the importance of teaching and learning of the Civil Technology practical component, it was discovered in all the three schools that practical lessons are not time tabled. However special arrangements are made towards the end of the year, usually around September for the learners to spend time in the workshop in order to complete the project for moderation. This means that learners do not have an opportunity to attend practical lessons on a weekly basis during the year. The basic principle of integration of practical and theory is that theory and practical should be time-tabled together, according to the principle of integration. The findings are supported by a meeting of the Bureau of the Conference of Ministers of Education of the African Union (COMEDAF II, 2007) report that offering technology education practical in schools is unlikely to be effective because the practical requires time which is too expensive to provide in all schools.

Educators should be well trained by Higher education institutions to conduct practical activities with learners to equip them with marketable skills for sustainable economy

after grade 12. Technology teacher education and training should include regular exposure and visit to related industry in order to keep abreast with the latest technological development. In their mathematics, science and technology strategy the department of basic education in South Africa should focus more on technological literacy development by equipping schools with relevant materials and equipment.

References

Aliyu, A.S. 1995. *Laboratory Skills- A prerequisite for effective Agricultural Science Teaching. Paper presented at Science Teachers Association Workshop*

 Anyakoha, E. U. 1992. *Development and utilization of facilities for home economic education program in Nigerian schools and colleges for manpower development*. *Nigerian Vocational Journal.* 2(1), pp. 16 – 24.

Apagu, V.V., & Andural, S.I. 2007. *Refocusing Nigerian vocational education for relevance and sustainable development. Multidisciplinary Journal of Research Development.* 9*.* 1 December, 2007

Bjurulf, V., & Kirlbrink, V. 2012. *Transfer of knowledge in technical vocational education:A narrative study in Swedish upper secondary school. International Journal for Technology and Design Education. Springer Science Business Media*.08 February 2012

Bacchus, K. 1988. *The Political Context of Vocationalisation of Education in the Developing Countries.* In J. Lauglo & K. Lillis (Eds). *Vocationalisation Education: An International Perspective*. Oxford: Pergamon Press, pp. 29-44.

Brunette, H. C. 2006. *Technical education in Namibia: past trends, present circumstances and future prospects.*

COMEDAF II (Bureau of the conference of the Ministers of Education of the African Union). 2007. *Harmonization of Higher Education Programmes in Africa: strategy for the African Union. Ethiopia: Addis Ababa.*

Department of Education. 2005. *National Curriculum Statement- Civil Technology* (General) [Online].Available from: www.education.gov.za

Department of Basic Education. 2011. *Curriculum Assessment Policy Statements* (CAPS) - civil technology. Available from:www.thutong.doe.gov.za/Resource download.aspx?

Department of Education, Papua New Guinea. 2006. *Design and Technology Subject Field Lower Secondary Syllabuses. Papua New Guinea: Department of Education*

Department of Education. 2003. Implementation of Revised National Curriculum (Grade R-9). Pretoria: Government printers.

Department of Education. 2000. National Curriculum Framework for Further Education and Training. Draft Document, Pretoria; Government Printers.

Department of Labour. 1998. *Apprenticeships* [Online].Available from www.labour.gov.za

Fritz, A. 1996. Reflective practice: enhancing the outcomes of technology learning experiences. The Journal of Design and Technology Education, 1(3), pp. 212-217.

Galluzo, G.R. 1996. The standards have come. *J. of Industrial Teacher Educ*., 34, **1**, pp. 11-13

Gamble, J. (2003) *Curriculum responses in FET Colleges* (Online).Available from: www.hrscpublishers.co.za .Pretoria: HSRC Press.

Grant, L., Stronge, J.H., & Popp, P. 2008. *Case studies of Award Winning Teachers of at Risk/Highly Mobile Students*

Ijambo, T.C.K. 2001. *State, Region, Ethnicity and Educational Inequalities inPostcolonial Namibia*. Unpublished PhD thesis, Michigan State University.

Johnstone, A.H., & Al-Shuaili, A. 2001. *Learning in the laboratory; some thoughts from the literature·*17 September 2001.

Kennedy, O.O. 2008. *Reappraising the Work Skill Requirements for Building Technology Education in Senior Secondary School for Optimum Performance in Nigeria*. 3(2). IDOSI Publications

Kennedy, O.O. 2011. *Philosophical and Sociological Overview of Vocational and Technical Education in Nigeria. American-Eurasian Journal of Scientific Research*. 6(1).IDOSI Publications

Kolb, D. A.**,** Boyatzis R, E., & Mainemelis, C .1999. *Experiential Learning Theory: Previous Research and New Directions.*

Kolb, D.A. 1984. *Experiential Learning: Experience as the Source of Learning and Development*. Prentice-Hall, Inc., Englewood Cliffs, N.J.

Kolb, D. A. 1979. *Organizational Psychology*, *a Book of Readings*.

Lauda, D.P. 1988. Technology education. In Kemp W.H & Schwaller (Eds.), Instructional strategies for technology education: 3-15. Glencoe Publishing Company

Letsie, L.E. 2003. *Vocational –Technical Education and Training in South Africa* [Online]. Available from:http://upetd.up.ac.za/thesis/available/etd-0318200

Makgato, M. 2011 Technological process skills for technological literacy: a case of few technology teachers at schools in Tshwane North District D3, South Africa. World transaction on Engineering and Technology Education. Vol 9 (2), pp. 119- 124.

Makgato, M., & Mji, A. 2006 Factors associated with high school learners' poor performance: a spotlight on mathematics and physical science. South African Journal of Education. Vol 26 (2), pp. 253 – 266.

Martin,D.J.,Dakers,J., Duvernet,L. Kipperman, D., Kumar,K., Siu, K.W.M., Thorsteinsson, G., & Welch, M. 200). In search of a sustainable future: an international overview of the contribution from design and technology education. The Journal of Design and Technology Education. 8(3), pp. 137-149.

MBESC. 2002. *Annual Report of the Ministry of Basic Education, Sport and Culture* (Online).Available from www.nied.iiep.unesco.org .Windhoek: MBESC.

Merriam, S.B. 1998. *Qualitative research and case study applications*. A Francisco: Jossey-Bas

McGrath, S. 1998. *National policies and institutional practices: the credibility gap in South African education and training reform. Journal for Vocational Education and Training*.50 (4), pp.503-518.13 December 2006

Mjelde, L. 1995. *Activity pedagogy: How does it really work? In Heikkinen (Ed) Vocational education and culture: European prospects from theory to practice*. Tampere. University of Tampere Press.

Mwaokolo, P.O.E. 2003. *Related thoughts in vocational education*. [Online]. Available from:www.searchworks.stanford.edu/view/5968659

National Unions of Teachers (NUT). 2011. *Safety in practical workshops*. [Online].Available from: www.teachers.org.uk.

Nwakile, I.C., & Oloruntimehin, D. 2010. *Problems and prospects of Nigerian educational system viz a viz teacher education programme .Journal of Qualitative Education*. [Online] 6(1) **.**Available from www.wesoedu.com

Nze, J.S.B., & Ginestie, J. 2011. *Technical and vocational teaching and training in Gabon: how future teachers build their vocational identity? International Journal for Technology and Design Education.* 22:pp. 399–416. 11 January 2011. Available from:http://www.springerlink.com/content/1547 x 2722ul.

Okorie, J.U. 2001. *Vocational Industrial Education League of Researchers in Nigeria*. Bauchi.

Osuala, E.C. 2004. *Foundations of Vocational Education*. Enugu: Cheston Agency Limited.

 Puyate, S. T. 2002. *Survey of Vocational Education Facilities in Government Technical Colleges in Rivers State. Journal of Nigerian Association of Teachers of Technology* .4(1), 175 – 181.

Rasinen, A. 2003. An analysis of the technology education curriculum of six countries. Journal of Technology Education, 15(1): URL: http://scholar.lib.vt.edu/ejournals/JTE/v15n1/rasinen.html

Rosa, J., & Feisel, L.D. 2005. *The Role of the Laboratory in Undergraduate Engineering Education*. *Journal of Engineering Education.* January 2005.

Seiter, J. 2009. *"Crafts and technology" and technical education" in Austria. International Journal for Technology and Design Education*. 24 September 2009

Simiyu, J. W. 2009 *Revitalizing Training Institute in Kenya: A case study of Nairobi Technical Training Institute, Eldoret*. Germany. UNESCO-UNEVOC *International Centre for Technical and Vocational Education and Training*

Stainaker-Key, J. 2014. The challenging road ahead. Skills development-bridging the skills divide Business Times. 18 May 2014. Pp. 1-64

Umar, I.Y., & Ma'aji, A.S. 2010. *Repositioning the Facilities in Technical College Workshops for Efficiency: A Case Study of North Central Nigeria*. *Journal of stem teacher education*. **.**47(3)

Uwameiye, R. 1993. *Some factors militating against the effective teaching of introductory technology in Bendel State schools. International Journal of Education Research.* 5:16-22.

Uzoagulu, A. E. 1992. *Towards an Effective Equipment Management (EEM) in Schools for Economic and Technological Self-reliance. A paper presented at the 7th annual conference of the NVA held at FCE (T), Umunze*. November 25th – 28th.

Walmsley, B. 2003. Partnership-centered learning: the case for pedagogic balance in technology education. Journal of Technology Education. URL: http://scholar.lib.vt.edu/ejournals/JTE/v14n2/walmsley.html

Unlocking Technology Education teachers' potential constituted creativity and innovation space on their learners

Tomé Awshar, Mapotse
University of South Africa, College of Education
mapotta@unisa.ac.za;

Abstract

The education landscape is changing rapidly and not only in South Africa, but throughout the whole continent of Africa. Besides this sporadic change, teachers are still poorly grounded in pedagogy and content knowledge of Technology Education. Technology Education (TE) has been introduced as a new subject nationally and globally just few decades ago. Teachers and learners are still experiencing hurdles in implementing TE. It is the supreme art of an action research practitioner to awaken the joy of tapping the potential and creative expression of sharing TE knowledge with the teachers as co-researchers. No education system can be better than its teachers, hence TE teachers were emancipated through action research (AR) to teach all the themes in one academic year. This action research (AR) study does not blame the limited teacher training in TE as its intention was to empower such. The study was underpinned by critical theory in using the Mapotse cascading paradigm. Focus group (interviews) was used as the method to engage these TE teachers. From the findings of the study, it has been proven that the AR approach study can be used in the 21st century as a skill to emancipate unqualified and under qualified Technology teachers within six-weeks-long AR cycles. TE teachers' potential was touched base with; as a result their learners were inspired to display creative and innovative projects in their technology class without any fear of being wrong.

Keywords: Technology Education, Creative and Innovative, Critical Theory, Mapotse Cascading Paradigm

1. Introduction

Hannaway (2016:122) stressed that 'Technology in this age is ubiquitous and is changing the way that individuals live, work and play'. Learners therefore need the 21st Centaury skills from a competent teacher to be able to comprehend development and changes in this technological era. Teachers need to be developed continually and continuously.

Makhanya (2013) urges that teachers' professional development should be continuous especially in rural and under-resourced schools. He further emphasise that poor schools will continue to bear the brunt of unsavoury results unless radical interventions are implemented. As a researcher from the University of South Africa (Unisa) I have embarked on a community engagement (CE) project as a way to intervene with teachers at Siyafunda Secondary School so as to bring the change within learners' learning and teachers teaching of Technology subject. So many researches were undertaken and few focuses on action research within community engagement.

Some scholars in the Technology field have engaged in research targeting variety of aspects of TE, for instance De Vries (2007), Middleton (2009), Nkosi (2008), Potgieter (2004), Pudi (2005), Stevens (2006) and Williams and Gumbo (2011). The aforementioned scholars belonging to both national and global villages and have used some common instruments or similar approaches to gather their data and little has been done in using action research approach within community engagement to emancipate Technology teachers and conscientice them to constitute creativity and innovation within their learners. With this study, I want to attempt to fill that gap by sharing on how action research can unblock teachers' potential. I will be sharing those technology teachers' experiences as a critical realist using a Mapotse cascading paradigm to guide the study and also underpinning this study through critical theory.

2. Theoretical framework

Theory is also an explanation that discusses how a phenomenon operates and why it operates as it does and it serves the purpose of making sense out of current knowledge by integrating and summarizing this knowledge, and thus it can be used to guide research by making predictions (Johnson & Christensen, 2004). Theory in the researcher's thought will help to make research decisions and provide a sense of the world around.

2.1 The value and application of critical theory in this study

In most qualitative studies, theory comes at the beginning and provides a lens that shapes what is looked at and the questions asked especially in a transformative research (Creswell, 2014). Critical theory indicates that a fundamental dialectical relationship between theory and practice are indivisible (Tooley, 2000), especially in Technology. This aligns well with my understanding of Technology Education as fundamentally a hands-on enterprise. Hands-on in Technology must be taken to refer to learning through experiences, that is, through practical engagement in investigating, designing, making, evaluating and communicating ideas and plans (Department of Education [DoE], 2003). Approaching Technology theoretically is unfathomable.

2.2 Cascading paradigm – 'each one, teach one'

The paradigm being used to guide the study is labelled Mapotse Cascading Paradigm in the sense that co-researchers end up running the project with or without AR practitioner. During project initiation I took the first TE teachers from Siyafunda and spend the whole year with them on AR emancipation spiral cycles of observation, planning, action and reflection per term covering all the TE themes. I serve as an AR practitioner and TE teachers serve as participants. As I adopt a school per year, the TE teachers from the adopted school serves as participants, the once emancipated teachers are elevated to be practitioners and I become the facilitator. In short each year we change our role as we add a new cohort of teachers into the programme.

3. Conceptualization

To avoid miscommunication, definition and explanation of terms are necessary, and to create a common frame of understanding, which increases the effectiveness of communication (Pudi, 2007). The following two concepts will be defined or explained in the context of this study: Community Engagement and Action Research.

3.1 Action research

Action research is a form of collective self-reflective enquiry undertaken by participants in social situation in order to improve rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situation in which these practices are carried out. Groups of participants can be teachers, students, principals, parents and other community members – any group with a shared concern (Kemmis & McTaggart, 1988). Action research is a process, in which participants examine their own educational practice systematically and carefully, uses the techniques of research (Ferrance, 2000).

AR was used as a means for radical interventions and it was implemented in this participating school. The AR cycles and spirals activities of observing, planning, acting and reflecting manage to professionally develop TE teachers from low self-esteem of teaching TE to a remarkable increased TE didactic and pedagogic knowledge levels. This AR activities were conducted during bi-monthly community engagement weekly sessions with the TE teachers.

3.2 Community engagement

Since this paper is focused on teachers the researcher therefore proposes the definition of CE to be in the following manner:

Community engagement is a regular interaction process with incapacitated teachers as a community of co-researchers led by an action research practitioner for emancipation purposes in pursuit of some new teaching skills, methods and approaches within their cultural context so as to enhance learners' performance and teachers' achievement.

As an Action Research (AR) practitioner, it's almost practically impossible to conduct CE activities without the AR components surfacing. A good CE activist will know when to infuse AR strategies within CE processes. One Higher Education Institution (HEI) in South Africa defined CE as, 'the continuously negotiated collaboration and partnership between the HEI and the interest groups that it interacts with, aimed at building and exchanging the knowledge, skills, expertise and resources required to develop and sustain society', (University of Free Sate, 2006).

4. Research problem

Technology is a late comer within school curriculum both nationally and internationally and therefore it has posed number of challenges different as opposed to other subjects (Mapotse, 2014).

4.1 Aim of the study

The main aim of this study is to confirm that the use of action research initiative during community engagement can unlock teachers' potential and lead to creation of an atmosphere where TE leaners can be creative and innovative. The action research (AR) study with the senior phase Technology Education teachers at Tshwane South District of Gauteng Province was motivated by the fact that TE is still a hurdle for teachers' pedagogy and impediment for learners' comprehension.

4.2 Problem Statement and research question

I found out when I arrive at Siyafunda Secondary School that teachers were in despair to teach this subject. This anxiety was coursed by the fact that these TE teachers are

underqualified and/or unqualified to teach TE subject. After reconnaissance study these TE teachers did welcome the rollout of AR with them. I run with them for the whole year in unpacking both their TE district workschedule and Technology policy document.

This focus group session with these TE teachers was solemnly intend to respond to this research question, *How can action research unlock teachers' potential which sub-sequentially constitute innovation space and creativity on their learners?*

5. Research methodology
The research methodology comprises primarily of two sections and those are the research design and research methods.

5.1 Research design
This was a qualitative study reporting a case of one school. The study was deeply immense in action research approach.

5.2 Research methods
- **Sampling**

With the guidance and advice from my wife when I asked her I would like to embark on community engagement project with Technology teachers and she encouraged me to go new settlement schools. These schools have been erected with iron bars and solid metal plate structures. With no air conditioners, these schools are cold in winter and hot in summer. I approached one school in squatter camp and I found that it has three (3) teachers which are teaching Technology. These teachers were teaching only Grade 8 and 9 as these are the grades that offer Technology at senior phase level in Siyafunda Secondary School.

- **Data collection instrument**

For the tenacity of this study, I will be reporting about the focus group (interviews) conducted so as to assess progress made thus far with these TE teachers. The reasons of this focus group session was to gather some information about the journey travelled together with TE teachers' in their teaching and learning of Technology' subject. The idea is to explore how AR interventions contributed to improving TE teachers' pedagogy and didactics. Siyafunda is a quintile one school situated within a needy community, who are low class income earners.

During the interviews teachers' about their classroom practices few things were also highlighted as part of our AR reflections. The reflection is conducted after a year of interactions between all parties involved in both CE and AR activities. The following series of six (6) predetermined questions served as a guide for the research dialogue between the participants (TE teachers) and I (AR practitioner). The questions were asked to determine as to whether after a year of interaction action research manages to unlock teachers' potential which sub-sequentially constitute innovation space and creativity on their learners?
  - (a) What have you learned from AR contact sessions since we were together for more than a year in this TE professional development journey?
  - (b) Which Technology areas are you now able to teach after our AR intervention that you couldn't teach before?
  - (c) What interaction has AR build among TE teachers within Siyafunda Secondary School?
  - (d) Is there any setbacks you like to highlight from our AR contact sessions or Technology subject itself?

(e) Which area(s) in Technology do you strongly feel you still need some grounding?

(f) Any recommendations you had for action research or Technology subject going forward?

6. Research findings

These interviews resulted in interesting conversations which among other things, reinforced that AR was the desired emancipation approach to these TE teachers. The TE teachers' were more willing to share their experiences and more open to be engaged at any level of future planning.

The questions kept the interview facilitation more focus as teachers voiced out their responses. Most of the teachers' responses are highlighted per question below:-

(a) What have you learned from AR contact sessions since we were together for more than a year in this TE professional development journey?

- o *Prof we have learned lot of things, among others, on how to present Technology subject properly to the learners;*
- o *We can now teach all the themes in Technology but before you come up with this intervention it was difficult to address some themes;*
- o *There are topics that we totally never teaches them to the learners e.g. electrical systems and control: different gates – AND gate and OR gate; resistor colour coding; and their application;*
- o *Our learners Prof are now able to do projects per term within the TE theme in our annual workschule.*

(b) Which Technology areas are you now able to teach after our AR intervention that you couldn't teach before?

- o *We were totally not teaching our learners drawing because we were not good with that at all since you came and taught us were to start in teaching learners drawing like isometric; 2D; 3D we are now able to teach it;*
- o *We have now seen the resistor and we know its function we can now engage our learners with questions around resistance;*
- o *We can now use a multi-meter to measure in the circuit and electronic components out of the circuit;*
- o *We can take our learners through technological steps of Investigate, Design, Make, Evaluate and Communicate.*

(c) What interaction has AR build among TE teachers within Siyafunda Secondary School?

- o *Before you arrived each Technology teacher was doing his or her own things at his or her own little corner;*
- o *After your intervention we almost do things together like giving learners same tasks; writing same test; prepare together;*
- o *As we are now sharing everything if one teacher is absent the other can be able to handle his/her class;*
- o *It is now easy to assess learners as we can now incorporate other forms assessment including projects assessment.*

(d) Is there any setbacks you like to highlight from our AR contact sessions or Technology subject itself?

- o *In our Technology subject there is no set back but regarding the contact session we are worried about time;*

- o *The two hours spend for four days in a week bimonthly is not enough to fully capacitate us;*
- o *We wish the contact sessions could be extended into weekends so as to help learners solve their school and community problems technologically;*
- o *School holidays could also be used for contact sessions especially in guiding learners about the design process when they do their TE projects.*

(e) Which area(s) in Technology do you strongly feel you still need some grounding?
- o *I need help in calculations of things like power, velocity, mechanical advantage;*
- o *My maths and science is not that good hence I struggle to apply a formula;*
- o *We need support from parents and school manage team need to by us basic hand tools;*
- o *Basic resources are needed to engage our learners with some demonstration lessons and make TE subject interesting to them.*

(f) Any recommendations you had for action research or Technology subject going forward?
- o *Technology is not well constituted at school level I therefore recommend that what you have stated with us you can expand it to a nation scale;*
- o *We need your help in structuring TE research problems within our school or the surrounding community;*
- o *As we are now able to embark on projects with our learners by using waste material we will really appreciate your intervention is assessing learners projects;*
- o *We really like to be sponsored on yearly basis, like as you did this year Prof, for us to attend Technology related conferences.*

7. Data analysis

Few steps that are earmarked by Creswell's (2009) were followed in analysing data. The initial step was to transcribe the focus group discussions onto an MS Word document. The transcripts were thoroughly read by the researcher so that a general sense of the data could be arrived at. Member checking was undertaken with the co-researchers to verify what could have been missed during the discussion process and to ascertain what was captured during the interviews is a true reflection of our discussion. Of importance was to get the overall depth, and credibility of the information (Creswell, 2009). The researcher approached the co-researchers with predetermined questions since this was assessing the emancipation progress and the impact of AR sessions conducted thus far with the TE teachers. What came out of teachers' responses can be grouped as follows:
- (a) In one academic year TE teachers are now able to teach all the themes as prescribed by the Provincial Ministry of Education and assess them using variety of methods;
- (b) TE teachers can now take their learners through drawing skills and system & control theme under resistance. These are some of the items they never taught to their learners in the past.
- (c) Few 'Cs' have been developed among the TE staff of Siyafunda Secondary School which include but no limited to communication, collegiality, confidence, companionship, considerate, consultation, cooperation, etc.
- (d) Contact session time to be increased by including if possible weekends and school holidays.

(e) Since TE staff at Siyafunda Sec School has low background with both Mathematics and Science, more calculations with them should be conducted until they are used to apply the formulae correctly. We (researcher and co-researchers) need to lobby for participation of both the parents and school management team.

(f) Technology awareness is highly recommended as well as more sponsorship on exposure to attend national and international Technology related conferences like SAARMTE, ISTE, PATT, etc.

9. Conclusions

Technology Education (TE) teachers' were emancipated to teach the subject with confidence and every chance of success through action research spiral cycles. The TE teachers have been emancipated to tech themes of Technology which they normally use to avoid in the past. The empowerment cycle programme with these unqualified and/or underqualified teachers followed the circuit theme as per their workschedule and has yielded the following:-

(a) AR contributed to TE emancipation;

(b) Emancipated teachers can now engage their learners with projects;

(c) Most of the TE themes could now all be confidently be taught and those that still need to be stressed were made explicit;

(d) Promotion of collaboration and interaction within TE colleagues within the school is now strengthened;

(e) Any holdup with reference to contact session and Technology subject have been addressed;

(f) Recommendations for future engagement were highlighted.

A rapport was established with TE teachers as I moved from emic AR researcher to etic AR practioner. TE teachers take the role of co-researchers in my community engagement project and were elevated to a new level yearly. As a new school is recruited on yearly basis that means these teachers are now prepared to take the reins with the new cohort of TE teachers from another school hence the implementation of the Mapotse Cascading Paradigm.

This paradigm of 'each one, teach one' has achieved two standing achievements: 1) unlock TE teachers teaching potential; 2) reveal learners' creativity and innovation in designing technological projects that solve their immediate school problems. In conclusion, I will recommend that the higher education institutions, especially universities, embark on community engagement services with Technology teachers from their nearby schools. This partnership will strengthen the teaching of Technology by TE teachers and its learning thereof by TE learners. In this study action research with technology teachers manages to close the technological pedagogic content knowledge and didactic gap.

References

Creswell, J.W. (2009). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches,* 3rd Edition. Thousand Oaks, California: Sage.

Creswell, J.W. (2014). *Research Design: Qualitative, Quantitative, & Mixed Methods Approaches (4th ed).* London: SAGE.

Department of Education. (2003). *Revised National Curriculum Statement Grades R-9 (Schools): Teacher's guide for developing learning programmes Technology.* Pretoria: Government Printers.

De Vries, H.L.M. (2007). Scenarios: guidance for an uncertain and complex world? In R.

Constanza, L. Graumlich, W. Steffen (Eds.), *Sustainability or Collapse?* An integrated History and Future of People on Earth, MIT Press.

Ferrance, E. (2000). *Action research*. Virgin Island: Brown University

Hannaway, D. (2016). Learners' profiles when experiencing Technology-based learning in the Foundation phase. South African International Conference on Educational Technologies (SAICET). Conference proceedings with the theme: "Empowering the 21st Century Learner", 24-26 April 2016, Manhattan Hotel, Pretoria.

Johnson, B. & Christensen, L. (2004). *Educational research: Quantitative, qualitative and mixed*
approaches (2nd Ed.). Boston: Pearson.

Kemmis, S. & McTaggart, R. (1988). *The Action Research Planner*. Victoria - Australia: Deakin University Press.

Makhanya, S. (2013). Education needs good foundation to thrive. Unisa e-news. Retrieved from
 http://staff.unisa.ac.za/e-connect

Mapotse, T.A. (2014). An Emancipation Paradigm through Critical Theory in Technology
Education: an Action Learning paradigm. *Mediterranean Journal of Social Science*. 5(3): 484 – 493.

Middleton, A. (2009). Beyond podcasting: creative approaches to designing educational audio.
Learning & Teaching Institute, Sheffield Hallam University, Sheffield, UK. *Research in Learning Technology,* 17(2), 143–155.

Nkosi, D.F. (2008). *Technological process as a framework for the improvement of instruction of*
technology. MEd dissertation. Johannesburg: University of Johannesburg.

Potgieter, C. (2004). The impact of the implementation of technology education on in-service
teacher education in South Africa. *International Journal of Technology and Design Education,* 14, 205 - 218.

Pudi, T.I. (2005). Educator roles for Technology Education teacher- educator. *Africa Education*
Review, 34(1), 147-167.

Pudi, T.I. (ed). (2007). *Understanding Technology Education from a South African perspective,* (pilot edition). Pretoria: Van Schaik.

Stevens, A. (2006). Technology teacher education in South Africa. *International Handbook of Technology Education: Reviewing the past twenty years*. M. de Vries & I. Mottier (Eds.). Rotterdam: Sense

Steyn, G. M. (2010). Educators' perceptions of continuing professional development for
teachers in South Africa: A qualitative study. *Africa Education Review*, 2010, 7(1): 156-179.

Tooley, W. R. (2000). *Political rationality & government mechanisms: Maori education policy in*
 the new millennium. MA in Education dissertation. Auckland: University of Auckland.

University of Free Sate. (2006). Community Service Policy of the University of Free State. Bloemfontein, South Africa. Retrieved form
 http://supportservices.ufs.ac.za/dl/userfiles/Documents/00000/357_eng.pdf

Williams, P.J. & Gumbo, M.T. (2011). New Zealand Technology pedagogical content
knowledge. In *Pupils' Attitude Towards Technology (PATT) 25 and Centre for Research in Primary Technology (CRIPT) 8* on "Perspective on Learning in Design & Technology Education". Goldsmiths, University of London, 29 June 2011 – 06 July 2011.

Perspectives on subject knowledge in teacher education for secondary design and technology in England.

Mike Martin, Liverpool John Moores University
School of Education, Barkhill Road, Liverpool L17 6BD
m.c.martin@ljmu.ac.uk

Abstract

The 21st century skills that pupils will learn whilst undertaking design and technological activity is heavily dependent on the skills and knowledge of those teaching them. In a time of considerable change for teacher education in England, it is important to consider what it is that pre-service teachers of the subject need to know, and what factors affect the development of the skills and knowledge that they learn?

Research being undertaken at Liverpool John Moores University in England is focused on the lived experience of pre-service teachers as they develop their subject knowledge in design and technology whilst on placement. In framing the research an exploration of different perspectives on subject knowledge has been undertaken. This paper provides an overview of the different perspectives and links are made with a number of theories and concepts such as pedagogical content knowledge Shulman (1986), communities of practice Lave and Wenger (1991) and activity theory (Engeström, 2014).The paper concludes with a number of challenges to competence-based views of knowledge and raises questions about the development of subject knowledge of pre-service teachers of design and Technology.

Forms of knowledge in practice

In the context of exploring subject knowledge for pre-service teachers, defining the term 'subject knowledge', as it is understood in education, and specifically in teacher education, is a difficult task. Simply put, it can be considered the knowledge that you need in order to be able to teach. However, such a definition skims over deeper questions about the types of knowledge that are required for teaching and how they are interrelated. For a practical, and at times creative, subject such as Design and Technology definitions of subject knowledge can be very open to interpretation. Some overview of key terms used to describe knowledge in the subject is useful.

The Interim Report (DES, 1990) that led to the first national curriculum for the subject in England included the description of procedural knowledge (knowing that) and provisional knowledge (knowing how). Since that time the authors of curriculum documents have made use of such a dualism in describing pupils' capability. This continues today with the description of tasks such as 'mostly making' and 'mostly designing' (Barlex).

In addition, authors such as McCormick (1997) refer to strategic knowledge which comes into play when decisions are made about how to proceed when designing and making. With a focus of making skills, the acquisition of tacit knowledge to develop 'mastery' (Dreyfus & Dreyfus, 1986) of materials and processes has also been an important part of the subject.

Any model of subject knowledge within design and technology may have several aspects and likely to involve a blend of conceptual, procedural, tacit and strategic knowledge embodied by the individual. How theses aspects are manifested in practice varies from school to school. Differences between individual teachers may account for such variation and the range of projects undertaken by pupils. What emerges is a picture of the subject with overarching categories of knowledge, such a food and textiles, within which there can be variations in delivery as long as key concepts are maintained.

Any attempt to define subject knowledge can also easily end up with a simplified and meaningless statement that reflects a positivistic and reductionist view of the world. Keeping an open mind, and not imposing theoretical structures, is consequently important for anyone engaged in empirical research.

Subject knowledge in teacher education

Developing appropriate subject knowledge is an essential part of becoming a teacher. Given the short period of time that most pre-service teachers have to develop their understanding of subject knowledge, how exactly they develop their knowledge is of critical importance. Course of initial teacher education are expected to audit beginning teachers subject knowledge and track this throughout their training. An assessment of such tracking has formed part of the inspection regime (Ofsted, 2008) for some time, making it a priority for teacher educators in an age of considerable accountability. Such was the interest in subject knowledge as a part of teacher education in 2007 that the Training and Development Agency for Schools produced a booklet entitled *Developing trainees' subject knowledge for teaching* (TDA, 2007) and held national subject seminars to discuss it. It has remained significant ever since.

Ellis (2007b) suggests that focusing teacher education's work on stimulating, supporting and, indeed, researching subject knowledge development in school settings also enables us to take subject knowledge much more seriously than getting pre-service teachers to tick lists and identify 'gaps' (p459). Such benefits are reflected in the considerable amount of research and writing about teacher education and the experience of pre-service teachers through course of training. Some of this research is focused on describing the very nature of subject knowledge such as the work of Andreotti and Major (2010), Ellis (2007b) and Watzke (2007) whilst others take issue with the subject-specific concept as a whole McNamara (1991). Other authors explore the experience of pre-service teachers such as Burn, Childs, and McNicholl (2007) and their interpretation of subject knowledge Herold and Waring (2011). There are also those that seek to find ways of assessing and improving subject knowledge such as Mantyla and Nousiainen (2014) and Lannin et al. (2013) addition the issue of transition from university to school context has been explored by authors such as Green (2006). Much of this work is subject oriented with authors using subject specific case studies to draw out broader issues. Very little of this, however, has been done in relation design and technology as a subject. What has been done in the subject is to consider professional knowledge, part of which is subject knowledge.

The development of professional knowledge for teachers of Design and Technology has been the focus of a number of authors since the development of Design and Technology as a national curriculum subject. Most of what has been written is related to the Developing Professional Thinking (DEPTH) project which emerged from work done at the Open University. The DEPTH project involved the use of a graphical tool to help pre-

service teachers reflect on their personal subject construct, considering what was referred to as their school knowledge, subject knowledge and pedagogical knowledge. The graphical tool was used over a number of years and across a number of countries (Banks et al., 2004), proving a useful tool to help pre-service teachers frame their experience. In relation to subject knowledge, a number of issues emerged from this research including pre-service teachers' background knowledge and the effect that placement settings have on the knowledge acquired.

Common in what has been written about subject knowledge in other subjects (Lannin et al., 2013)is the concept of pedagogical content knowledge (PCK) as first developed by Shulman (1986). Despite it's popularity, even in the present day, it is felt not to be an appropriate concept for Design and Technology (Williams, Eames, Hume, & Lockley, 2012) given its inherent assumptions about the fixed nature of knowledge.

Codified subject knowledge
The subject of design and technology involves practical activity to develop three-dimensional products. Some of its roots lie in the various craft professions where a narrow range of processes were available to make clearly defined outcomes in ways that could be repeated. Apprenticeship enabled newcomers to learn the very specific techniques required along with tacit knowledge required to develop 'mastery' (Penfold, 1988). Currently, with the wide range of tools, machines and techniques available it is possible to use different manufacturing techniques to achieve the same outcome. As a consequence of this, there is, for many processes, no correct way to do it. This can lead to a situation where different teachers go about even the simplest task, such as marking out a piece of wood, in different ways. For pre-service teachers this is not always helpful and can lead to tension when working on placement where processing techniques are different than those that they have developed themselves.

Given the open-ended nature of the subject, the experience of the subject that pupils have is shaped by the teachers and departments within which they are designing and making. Any limitations in the skills and knowledge of teachers can therefore limit the experience that pupils have, making it important that those entering the profession have a clear understanding of how materials can be processed in order to realise design intentions and create useful products. It could be argued that more important than the prescribed curriculum as defined by government is the curriculum experienced by pupils in schools. Whilst the curriculum has developed considerably over time (Martin & Owen-Jackson, 2013) the extent to which departments and individual teachers have kept up to speed is unknown. Grounded research on this needs to be undertaken if we are to truly know the skills that pupils have developed through units of work defined by practitioners across the country. This will give an insight into the skills that pupils actually gain for the 21st century.

As has been seen above, defining the subject knowledge required to teach the subject is not straightforward with the number of variables that need to be taken into account. On top of this it is necessary to consider factors affecting the acquisition of subject knowledge for individuals who are learning skills of teaching and of working in unfamiliar environments. It has been the practice of those running teacher education course to audit the subject knowledge of pre-service teachers and set an expectation that they will address 'gaps' in subject knowledge whilst on placement. Such an approach, driven from a set of fixed competences, reflects assumptions about the nature of knowledge within a curriculum subject. Ellis (2007a) challenges the assumption that subject knowledge is

often considered as static, unproblematic and developed by the individual. Rather, he presents a model that considers the agency of pre-service teacher within a dynamic system of knowledge framed within specific contexts.

On starting placement, pre-service teachers are likely to be faced with teaching areas of skills and knowledge already defined by the school, making opportunities for the development of new knowledge less than straightforward. Constraints of resources and timetabling are likely to have an effect on what is taught and, by implication, what pre-service teachers learn in order to teach. Accepting this view of the context-dependent nature of subject knowledge immediate brings into question the idea of one set of competences that need to be acquired by teachers of design and technology.

Learning new knowledge

So far the paper has explored knowledge in the subject, knowledge in teacher education as a whole, and subject knowledge as it is interpreted by schools. Another important perspective is that of the learner and consideration of the processes of knowledge acquisition. The research being undertaken adopts what Denzin and Lincoln (2011) refer to as a constructivist-interpretivist theoretical perspective. In doing so it is necessary to consider how knowledge is constructed whilst pre-service teachers are on placement. For example, to what extent is knowledge constructed by the individual (Von Glasersfeld, 1989) or co-constructed (Vygotsky, 1978) by both the pre-service teacher and the teacher responsible for mentoring them? Given the likely effect that the school placement will have on the development of knowledge, would a cultural-historical perspective (Engeström, 2014) be more appropriate?

In a similar way to the earlier section on knowledge conceived within the subject, it is suggested that no existing theoretical framework related to knowledge construction is, by itself, appropriate to be sued in looking at the phenomenon. It is better therefore to take a more grounded approach that considers what actually happens as a starting point.

Current context

Subject knowledge has remained high on the government's agenda for the last few years with the recent white paper (DfE, 2016). This, in part, reflects a view of teaching as the transmission of 'essential facts' to pupils.

School-centred training

The move towards more school-based training raises questions about how pre-service teachers of the subject will develop their knowledge and indeed what knowledge they will develop. Currently, many of those entering the profession will be required to undertake a course in subject knowledge prior to being accepted on a course of teacher education. Such courses are designed to provide basic skills and knowledge for specific material areas that will be useful in a variety of placement arenas. For pre-service teachers following a schools-direct driven course there may not be any such requirement and the range of skills and knowledge that they are exposed to will be determined by the experience they have in one particular placement arena.

Conclusion

Bringing together different perspectives it is clear that the subject knowledge of pre-service teachers is important, complex and dynamic. There are a number of research questions that need to be addressed if the phenomenon of subject knowledge development is to be understood.

What do pre-service teacher actually experience? Firstly is the question of what we know about the actual lived experience of pre-service teachers as they develop their subject knowledge. What is significant for individuals, and what is common amongst all of those entering the profession regardless of their specialism, need to be identified.

What influences the nature of knowledge developed? With the adoption of contemporary views of learning, it is accepted that subject mentors, who work with pre-service teachers in schools, are influential in determining the type of teaching that is undertaken and consequently the forms of knowledge that are acquired by the individual.

How do pre-service teachers learn new things? When faced with the prospect of teaching skills and knowledge outside of their experience, how do pre-service teachers go about learning what is required?

How does their experience relate to existing theories? Existing frameworks that exist for exploring subject knowledge, such as the DEPTH too and PCK impose structure on what is a complex and dynamic phenomenon that can, perhaps, only be understood by empirical research that privileges the voices of pre-service teachers as they struggle to develop the necessary skills and knowledge within their unique settings. Rather than work with established frameworks that are simplifications of a complex reality, as recognised by their authors, it would be better to explicate the lived experiences of pre-service teachers from their direct experience.

This paper has thrown light on different issues that help to contextualise the development of subject knowledge by pre-service teachers of Design and Technology. In doing so it has highlighted some of the things that need to be considered in order to develop a better understanding of what actually happens when they are on placement and the complexity of processes that are brought to bear and their knowledge develops over time. Given the significance of pre-service teachers knowledge as they become teachers of the subject it is surprising that there has been precious little empirical research undertaken in the last 25 years. New research is needed in this area that challenges the existing orthodoxy of teacher education of the subject in England and can throw fresh light on the lived experiences of pre-service teachers as they become those responsible for the education of our young people developing skills for the 21st century.

References

Andreotti, V., & Major, J. (2010). Shifting conceptualisations of knowledge and learning in initial teacher education in Aotearoa/New Zealand. *Journal of Education for Teaching, 36*(4), 441-459. doi:10.1080/02607476.2010.513857

Banks, F., Barlex, D., Jarvinen, E. M., O'Sullivan, G., Owen-Jackson, G., & Rutland, M. (2004). DEPTH - Developing professional thinking for technology teachers: An international study. *INTERNATIONAL JOURNAL OF TECHNOLOGY AND DESIGN EDUCATION, 14*(2), 141-157. doi:10.1023/B:ITDE.0000026475.55323.01

Burn, K., Childs, A., & McNicholl, J. (2007). The potential and challenges for student teachers' learning of subject-specific pedagogical knowledge within secondary school subject departments. *Curriculum Journal, 18*(4), 429-445. doi:10.1080/09585170701687886

Denzin, N. K., & Lincoln, Y. S. (2011). *The SAGE handbook of qualitative research / edited by Norman K. Denzin, Yvonna S. Lincoln*: Thousand Oaks, CA ; London : SAGE, 2011.

4th ed.

DES. (1990). *Technology in the National Curriculum*. London: HMSO.

DfE. (2016). *Educational Excellence Everywhere*. London: Department for Education.

Dreyfus, S., & Dreyfus, H. (1986). *Mind over machine: The power of human intuition and expertise in an era of the computer*. New York: Free Press.

Ellis, V. (2007a). *Subject Knowlegde and Teacher Education: The Development of Beginning Teachers' Thinking*. London: Continuum.

Ellis, V. (2007b). Taking subject knowledge seriously: from professional knowledge recipes to complex conceptualizations of teacher development. *Curriculum Journal, 18*(4), 447-462. doi:10.1080/09585170701687902

Engeström, Y. (2014). Activity Theory and Learning at Work. *Tätigkeit - Aneignung - Bildung*, 67. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=98820066&site=eds-live

Green, A. (2006). University to school: challenging assumptions in subject knowledge development. *Changing English: Studies in Culture & Education, 13*(1), 111-123. doi:10.1080/13586840500347475

Herold, F. A., & Waring, M. (2011). So much to learn, so little time…: pre-service physical education teachers' interpretations and development of subject knowledge as they learn to teach. *Evaluation & Research in Education, 24*(1), 61-77. doi:10.1080/09500790.2010.526203

Lannin, J., Webb, M., Chval, K., Arbaugh, F., Hicks, S., Taylor, C., & Bruton, R. (2013). The development of beginning mathematics teacher pedagogical content knowledge. *Journal of Mathematics Teacher Education, 16*(6), 403-426. doi:10.1007/s10857-013-9244-5

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.

Mantyla, T., & Nousiainen, M. (2014). Consolidating Pre-service Physics Teachers' Subject Matter Knowledge Using Didactical Reconstructions. *Science & Education, 23*(8), 1583-1604. doi:10.1007/s11191-013-9657-7

Martin, M., & Owen-Jackson, G. (2013). Is design and technology about making or knowing? In G. Owen-Jackson (Ed.), *Debates in design and technology education*: London : Routledge, 2013.

McCormick, R. (1997). Conceptual and Procedural Knowledge. *International Journal of Technology & Design Education, 7*(1/2), 141-159. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=22680174&site=eds-live

McNamara, D. (1991). Subject Knowledge and Its Application: Problems and Possibilities for Teacher Educators. *Journal of Education for Teaching, 17*(2), 113-128. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ433798&site=eds-live

Ofsted. (2008). *Framework for the inspection of initial teacher education 2008-2011*. London: Office for Standards in Education.

Penfold, J. (1988). *Craft, design and technology: Past, present and future.* Stoke on Trent: Trentham Books.

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher, 15*(2), 4-14. Retrieved from http://www.jstor.org/stable/1175860

TDA. (2007). *Developing trainees' subject knowledge for teaching*. London: TDA Publications.

Von Glasersfeld, E. (1989). Cognition, Construction of Knowledge, and Teaching. *Synthese, 80*(1), 121-140. Retrieved from http://www.jstor.org/stable/20116670

Vygotsky, L. (Writer). (1978). Mind in society: the development of higher psychological processes. Cambridge, Massachusetts: Harvard University Press.

Watzke, J. L. (2007). Foreign Language Pedagogical Knowledge: Toward a Developmental Theory of Beginning Teacher Practices. *Modern Language Journal, 91*(1), 63-82. doi:10.1111/j.1540-4781.2007.00510.x

Williams, J., Eames, C., Hume, A., & Lockley, J. (2012). Promoting pedagogical content knowledge development for early career secondary teachers in science and technology using content representations. *Research in Science & Technological Education, 30*(3), 327-343. doi:10.1080/02635143.2012.740005

Re-defining 21st Century Technological Practice: With acknowledgement to Pacey.

Ann McGlashan
Faculty of Education
University of Auckland
New Zealand
a.mcglashan@auckland.ac.nz

Abstract

A main intent of technology education is to prepare young people to be empowered to face their future as informed members of society. The attributes of such an informed person, who could confidently face a wide range of potential roles in 21st century life, would likely include the ability to think flexibly, imaginatively and courageously.

Such a person would also have developed a working knowledge and skill-set in technology related specialist areas. Each specialist area has a way of going about its practice driven by a way of thinking that is underpinned by and embedded in related and emergent knowledge to inform that practice. Practical skills and an understanding of associated codes of practice, protocol and related human and societal considerations that evolve through that practice are also developed.

It follows that learning about *technological practice* is fundamental to student learning in technology education. Therefore by providing rich learning experiences for students, within the broad field of technological activity and across a range of contexts, authentic *technological practice* will be evident in the classroom.

Pacey's (1983) model of *technological practice*, informed early Initial Teacher Education (ITE) programme planning, by providing a lens to view and find feasible parallels between authentic industrial and classroom technological practice.

This paper introduces an exploration into technological practices that are related to ITE students' feed-in careers. Findings compare and contrast contemporary industrial practice with Pacey's model as a viable guide to view and inform 21st Century pedagogy, practice and learning.

Keywords: Technological practice, communities of practice, authentic, pedagogy, classroom practice.

Introduction

Technology education has been a part of the New Zealand school curriculum for nearly twenty years. A review of the underlying guiding principles that informed initial programme planning, core pedagogy and learning of the technology learning area is long overdue.

Learning in technology, should at best, provide experiences that are authentic or relevant to the learner's life. Such activity will engage and encourage students to develop and resolve solutions to authentic societal needs, issues or opportunities.

Technology education aims to provide learning programmes that reflect the way groups of experts work together to develop outcomes within a wide range of contexts.

Theorist Arnold Pacey (1998) introduced the term *technological practice* after he observed parallels between the practice of technologists and medical practitioners. The term *technological practice* became a core principle of technology programmes, as it encompassed the range of complex activity within industry or company settings, while developing solutions to societal needs, issues or opportunities.

Industrial technological practice provides teaching and learning with a model of how people go about their daily work within a company or industry from across the broad field of technology related contexts. There are many processes going on in technological practice in collaborative ways towards the common goal of viable outcomes, to meet an identified or perceived societal need.

It is this overarching practice that we at best in technology education, hope to emulate within classroom practice. Learning through authentic practice enables students to develop tacit knowledge (Polayni, 1967) as they observe, explore and discover new strategies while participating in persistent problem solving in relevant domains (Bereiter, 1992). Bereiter also made comment on "what it means for a school to be a knowledge-building community (as distinct from a community in which activities go on that involve knowledge) "and that " many educators will "need concrete demonstrations, something that looks and feels different from what they are used to" (p.357) to make the change to constructivist learning within authentic contexts.

If learning in technology best reflects that of contemporary industrial practice then do the models of technological practice introduced in the mid '90s still provide relevant prompts to view and translate to current classroom practice? This paper shares an initial activity in the review of contemporary industrial practice using Pacey's model as a guide.

Theoretical background

The term technological practice defines the overall decision-making, thinking, actions and collaborations that occur within technological related enterprise or endeavour. Pacey's intent for the term technological practice gave emphasis to the whole activity and environment to support the activity. He provided a useful model of technological practice being comprised of three aspects that encompassed the human, values, technical, procedural and organisational conditions required to support all technological endeavour. Pacey's three identified aspects include the :

- Cultural aspect: goals, values and ethical codes, belief in progress, awareness and creativity.
- Organisational aspect: economic and industrial activity, professional activity, users and consumers, trade unions.
- Technical aspect: knowledge, skill and technique: tools, machines, chemicals, liveware; resources, products and wastes.

Pacey viewed the technical aspect on its own, as being a restricted meaning of technology.

Compton and Harwood (2003) identified specific aspects from across a range of technological activity and context that feature within technological practice that expand upon the human involvement within practice. These include:

- the perspectives of the people involved in the development;
- the capability of the people involved in the development;
- the range of technological knowledge, skills and resources available at any time;
- knowledge and skills from other domains as appropriate;
- the society and environment that impact on that development;
- the society and environment that the development will impact upon, (p.3).

They proposed that by providing opportunities for students to undertake their own technological practice, critique the practice of others, while becoming aware of the cultural and historical influences of related technology that students will become technologically literate.

In his research to establish a "simplified structure of" technological practice "and knowledge suitable for New Zealand schools." Gawith (2000) identified seven elements within the practice of technologists to inform teaching and learning. The first three elements all involved context and methodology included:

- society
- work environment
- purposeful action

the remaining four elements involved the skills, knowledge and actions of the individual technologist or team, these included:

- organisation
- information
- resources
- techniques (p.60).

Parallels can be made across all technological practice models with areas of variation expanding and enhancing, yet still aligning to Pacey's three main elements.

What goes on within company or industry practice involves numerous interconnected skills, knowledge, processes and practice, with each contributing specialist area viewed by Wenger (1998) as a *community of practice* in its own right. These contribute to the greater role of the company or industry's practice.

People with particular skills, values, beliefs and a way of knowing and doing to resolve the intended outcome of the group's activity carry out technological problem solving. Wenger 1998 defines communities of practice, around three dimensions:

- What it is about—its *joint enterprise* as understood and continually renegotiated by its members
- How it functions—the relationships of *mutual engagement* that bind members together into a social entity
- What capability it has produced—the *shared repertoire* of communal resources (routines, sensibilities, artifacts, vocabulary, styles, etc.) that members have developed over time.

Wenger (1998) further expands on the essential human interface component within communities of practice in his observation that

communities of practice develop around things that matter to people. As a result, their practices reflect the members' own understanding of what is important. Obviously, outside constraints or directives can influence this understanding, but even then, members develop practices that are their own response to these external influences" he

concludes that "communities of practice are fundamentally self-organizing systems" (p.2).

These work together with other related communities of practice within the company or industry practice to contribute towards the greater goal. Communities of practice within an industrial practice could include accountancy, marketing, design, engineering, digital, management, human resources, manufacturing, health & safety etc. depending on the nature and context of the practice and its contribution to society.

Reviewing technological practice - method

In preparation for the review into technological practice, coursework ethics approval was sought and gained to set codes of practice to protect all participants. Initial introductory letters are sent out to invite and explain participation in an interview. The review interviewers are initial teacher education (ITE) students, who have recently entered teacher training from technology related careers and study. These students are familiar with a particular community of practice. Sets of questions that have been developed by students to guide the interview are given to the company prior to the formal interview.

The review serves two main purposes. In guiding students to explore a technological practice of their choice they re - examine their own feed-in career practice. They find parallels between the visited practice and their own career experience. This helps ITE students to see the relevance of their background, through this experience to see a seamless translation to future authentic classroom practice.

Observations by Mc Glashan & Wells (2013) saw that the review helped to maintain confidence by recognising key aspects of student career background by building "conceptual bridges to educating about technology and the development of technological literacy." As students became familiar with the nature of an entire technological practice they could also see an application of seminal theory to the viewed practice. This enhances their understandings of the structure and extent of activities, culture and organisation within contemporary industry (p. 944).

Students then make a formal digital presentation to their peers on their findings with links made to the curriculum and implications for teaching practice.

Pacey's model of technological practice has been tested and remains the ITE programme's preferred model to align with the range of student selected visited practices. These include industrial practice relating to textiles/fashions, food/hospitality, engineering-related, digitally related, product and spatial design. The size of the visited practice can vary from a small one to two person operations to a large organisation with many staff.

To optimise the experience and instil ownership of the experience, each cohort of students discusses the nature and intent of Pacey's aspects. Students select prompt questions to drive discussion with the company representative to glean the most in-depth, perceptive response, to provide a comprehensive view of a technological practice.

Through the development of questions students bring their own career, life experience and perspectives to the discussion. Key principles such as those relating to sustainable development considerations arise to address as Pavlova (2007) proposed effective conceptualisation of education for SD. She saw this as necessary to generate understandings in young people that include both the notion that technological activity will fix the sustainability crisis (the techno-fix) and initiate wholesale transformation of human attitudes and values towards the natural world. Pavlova further states that it is now compulsory for all in industry to understand:

- How to use the right materials in order to avoid unnecessary energy consumption
- How to behave and work to minimise energy consumption.
- How to identify, source and use new, more efficient materials to save energy (p.12)

Industry visit questions to establish the nature of the visited practice.

Interview questions developed through discussion and prompted by Pacey's three aspects and descriptors are shared here to explain the breadth of coverage offered by Pacey's model. Further discussion and interrogation to extend understandings of what actually occurs in contemporary industrial practice is anticipated. This will guide pedagogy and enhance the translation of authentic practice from industry to inform learning in technology.

Cultural Aspects (goals, values and ethical codes, belief in progress, awareness and creativity)
- Can you explain the overarching goal or goals of your company?
- Is there a company vision, underlying philosophy or mission statement?
How does your company maintain focus on these?
- Where do you see your company in 10 years, 5 years time?
- Can you talk me through the history of your company?
- What are the main strengths of your company?
- How have you adapted to change, markets, and clientele?
- How has competition affected your company's practice?
- Does your company have a relationship with other companies nearby or in your field? How does this benefit your company?
- Can you describe the emotional and physical work environment that you provide for your staff?
- How do you foster creativity?
- How do you approach equity in your company e.g. wages, benefits, age, gender?
- How do you ensure that your staff maintains a healthy life/work balance?
- Can you describe incentives given to staff e.g. Holidays, professional development, over-time, flexible hours, bonuses, benefits, staff functions, long service leave, loyalty, discounts, bereavement and parental leave.
- Do you have incentives for staff when goals are met?
- Do you make allowances for individual cultural backgrounds/diversity?
- What is the company approach to employees origins (NZ or overseas)?
- How does the company address PR and 'or complaints processes?
- Do you incorporate team-building activities for staff? How important is this aspect to your company?
- Where do your workers spend most of their time?
- Can you describe their working conditions?
- Are there any areas that you see as requiring improvement?
- How do you address environmental/sustainability considerations in your company?
- What is the company approach to the sourcing of materials – locally produced resources or materials, rather than imported?
- What initiatives does your company use to adhere to health and safety requirements/national codes/ Accident Compensation Corporation (ACC)?
- How does the company interact with, benefit or support its community, whanau, iwi (indigenous Mãori terms for family and the group of people responsible for the area/land)

- How does the surrounding community affect your company?

Organisational aspects (Economic and industrial activity, professional activity, users and consumers, trade unions)

- Can you describe the management structure of your company?
- Do you have an open door policy, human resource (HR) facility?
- Can you describe the main criteria that you adhere to when looking for new staff?
- Do you recognise and support union membership? Can you explain?
- Are you able to be involved in apprenticeship schemes?
- Can you list the main codes of behaviour, rules or protocol you need to abide by?
- Can you talk me through the planning than needs to occur prior to and during production?
- What happens to the waste products from your industry?
- Is ongoing training, professional development (PD) available for your staff?
- Who are your clients?
- Who are your consumers?
- How do you reach your consumers, to establish consumer needs?
- Which marketing strategies do you employ?
- How do you maintain a contemporary approach to new technologies related to your industry?
- How does your company remain creative and progressive? Can you explain current initiatives?
- Can you explain the quality control methods employed within your practice?
- Do you outsource any aspect of your company practice?
- Can you share any details relating to the financial management, income and outgoings for your company?

Technical aspect (Knowledge, skill and technique; tools, machines, chemicals, liveware; resources, products and wastes).

- Can you describe the qualifications and prior training of your staff?
- What is the skill-set of your employees?
- Can you describe the on-site training for staff?
- How is design incorporated in your practice?
- Can you explain the processes used in your company from first instruction, idea through to marketing and delivery?
- What are the main modes of communication used in your company?
- How much energy does it take to run the company?
- Can you describe the machinery, plant, equipment, tools, and digital systems used in your company? Is this locally produced or sourced?
- Can you explain the processes used in your company?
- Can you describe the upgrading and maintenance of machinery?
- Where does your company source the raw materials required in your practice?
- Can you describe how your company manages waste disposal?

Conclusion

The development of interview questions guide the interview providing much to explain the nature of the visited practice. Students own the experience recognising apsects of their

own background to further see the application to school programmes. They can see the relevance of cultural aspects to value the societal and human interface with technological activity. The significant role that the physical and emotional working environment they see as directly transferrable to a learning environment. They see the planning, research, communications and ways of thinking and acting within the observed practice processes. They see the entire practice as it happens from inception, through the development of ideas to a final outcome. Depending on the scope of the practice they observe testing, trialling and the manufacture of outcomes to inform their pedagogy planning and teaching.

The experience of review into an actual industrial practice encountered by future teachers of technology provides direct and tangible links to inform authentic classroom technological practice.

References:

Compton, V., & Harwood, C. (2003). Enhancing technological practice: An assessment framework for technology education in New Zealand. *International Journal of Technology and Design Education*, *13*(1), 1-26.

Gawith, J. A. (2000). Technology practice: a structure for developing technological capability and knowledge in schools.

Mc Glashan, A. A., & Wells, A. W. J. (2013). The road less travelled: a pre-service approach towards the technology teaching profession. *International Journal of Technology and Design Education*, *23*(4), 939-952.

Pavlova, M. (2007, October). Two Pathways, One Destination–TVET for a Sustainable Future. In *Background paper for the UNESCOUNEVOC virtual conference* (Vol. 22).

Wenger, E. (1998). Communities of practice: Learning as a social system. *Systems thinker*, *9*(5), 2-3.

Polanyi, M. (1967). The tacit dimension.

Teacher educator perspectives on pedagogical modelling and explaining in Design and Technology: a Q Methodology Study.

*Matt McLain: Liverpool John Moores University,
UK
m.n.mclain@ljmu.ac.uk.*

Abstract

This paper builds on a previous study on the demonstration as a signature pedagogy in design and technology, this paper explores teacher educators' values on teacher modelling and explanation. In a previous study the participating teachers identified "competent management of the learning experience" as a significant factor in effective demonstrations, and in particular teacher competency, clarity and subject knowledge. The demonstration is a fundamental pedagogical tool for practical subjects where procedural knowledge is developed over time from observation and imitation to independence and adaption of technique. As such, it tends to align itself at the restrictive end of an expansive-restrictive continuum. This study builds on the developing exploration of the nature of the demonstration, exploring the subjective values of teacher educators. Q Methodology is used to compare and analyse the responses of the participating teacher educators. A Q-Set of statements, developed and refined with D&T teacher educators, relating to modelling and explaining, represents the concourse of opinions and perspectives. The sample is purposive, comprised of teacher educators. The findings represent a snapshot of subjective values, informing the wider discourse on signature pedagogies in design and technology education.

Keywords: demonstration; teacher modelling, design and technology, initial teacher education; teacher educator; Q methodology.

Introduction

McLain, Barlex, Bell and Hardy (2015) and McLain, Bell and Pratt (2013) postulated that the demonstration was a signature pedagogy, but had received little attention in pedagogical and research literature for design and technology, both in the United Kingdom and internationally. This was despite acknowledgement by Petrina that it was the "single most effective method for the technology teacher" (2007: 1). The demonstration is important in other subjects and has received some attention in in subject disciplinary literature, such as science (Milne and Otieno, 2007) and physical education (Mosston and Ashworth, 2002).

This study aims to continue to dialogue begun by McLain et al (2015) on the subjective views on teacher modelling and explaining in design and technology, focusing on teacher educators in the United Kingdom.

Literature review

The aim of this literature review is to present a rationale for the theorisation of teaching and learning in design and technology in the context of a challenging, contemporary, educational and political environment in England.

Current educational context

Emerging from craft subjects, design and technology was recognised as "educationally important" (DES and WO, 1998) from the introduction of the national curriculum in England (NCC, 1990). However, around 20 years later an expert panel report for the Secretary of Education (DFE, 2011) considered that practical subjects, including design and technology, art and design, and computer science, had "weaker epistemological roots" (p.24). This has been more recently realised in the curriculum through the introduction of the English Baccalaureate and proposals to extend the "school day to include a wider range of activities, such as sport, arts and debating" (DFE, 2016: 88, 95), potentially widening the gap between the core academic and the practical and creative subjects.   This is both a challenge for and to the subject community. 'For' in that it undermines the position it once held in the national curriculum, and 'to' as a prompt to address perceived disciplinary weakness and engage with research and theorisation subject and pedagogical knowledge.

Practical education and domains

Despite the importance laid on practical education in recent history (Claxton, Lucas and Webster, 2010a, 2010b; Dewey, 1916; Froebel, 1900), the emphasis in the current educational context has been on the cognitive aspects of learning. The popular taxonomy of educational objectives introduced by Bloom et al (1956) identified three domains of learning: cognitive, affective and psychomotor. The first, and most widely recognised, domain of the cognitive was initially defined by Bloom et al, though this was updated by Andersen and Krathwohl (2001) who were part of the original research team. The affective domain, relating to values and aspects of emotional intelligence, was defined by Krathwohl, Bloom and Masia (1964). However, the psychomotor domain remained untouched by those involved with the original identification of the three domains.

In her attempt to define the third domain, Simpson quotes Bloom (1956: 7-8) as having found "so little done about [the psychomotor domain]", and "[did] not believe the development of a classification of these objectives would be very useful" at the time (1966: 2). As the principle investigator, Simpson drew from expertise in practical subjects to describe a psychomotor domain (Figure 1).

Figure 10 Simpson's psychomotor domain

Perception	Observation and general perception
Set (or mindset)	Cognitive readiness for action
Guided Response	Imitation and mimicry when practicing actions
Mechanism	Emerging competence/proficiency, leading to independence
Complex Overt Response	Independence, automatic and accurate performance
Adaptation	Mastery and the ability to transfer skill/knowledge to other settings
Origination	The ability to create new approaches to activity

Several other researchers have also sought to define the psychomotor domain (Harrow, 1972; Dave, 1967) and redefine or update Blooms original work (Marranzo and Kendell,

2007; Andersen and Krathwohl, 2001). However, the role of the practical in education in the United Kingdom has arguably remained on the periphery, despite formal recognition of practical subjects in the National Curriculum since 1990.

Research of teacher modelling and explaining

In their small-scale study of 7 teachers, McLain et al (2015) identified the complexity of views on teacher modelling and explanation, which drew on generic and subject specific pedagogical knowledge. This, in turn, was viewed to rely on competent subject knowledge. The study correlated with Petrina's (2007) common components of a demonstration, in particular to the relevance' and application of practical knowledge, which rely on the specialist knowledge of the teacher.

The participants responses indicated that competence with subject knowledge was believed to "fundamental to effective teacher modelling" underpinned by "skilful pedagogical knowledge" and classroom management (p.274-275). The relationship and hierarchy of the teachers' beliefs was represented graphically (Figure 2), indicating the higher value placed on restrictive (teacher led and focused on the development of specific knowledge and practice) over expansive (learner led and open-end activity with multiple potential outcomes), which draws on Fuller and Unwin's (2003) work on learning environments.

Figure 11 Model of participant responses in McLain et al (2015: 275)
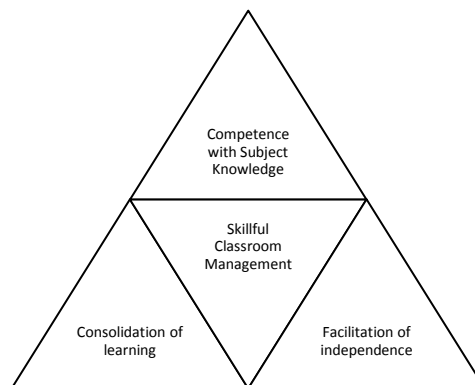
The restrictive-expansive framework, proposed by Fuller and Unwin, may be a useful tool for the design and technology community to consider when considering the intentions of a particular demonstration. For example, a restrictive demonstration might focus on specific procedures that must be correctly followed to achieve a successful outcome, which would tend to result in learners' made outcomes being similar. Whereas, an expansive approach would provide stimulus for open-ended, design-oriented activity, leading to a range of outcomes. The responses to McLain et al's study indicated that participant views on demonstration favoured statements on the restrictive end of the continuum (competence with subject knowledge and skilful classroom management), rather than the expansive (consolidation of learning and facilitating of independence).

Research design

The research question for this study was: What do design and technology teacher educators believe to be effective pedagogy modelling?

This study was conducted using Q Methodology (Watts and Stenner, 2012), which focuses on participants' subjective beliefs or "first person viewpoints" (p.4) "in pursuit of an explanation and new insight" (p. 39); in this case, into teacher educators' views on teacher modelling and explanation. The concourse of views is encapsulated in 62 statements developed for the initial study of teachers' views, conducted by McLain et al (2015), adopted for this study. The nature of these statements, developed through focus groups with school-based initial teacher education mentors and teacher educators, tends towards statements that would be generally supported as effective approaches. Within Q Methodology, Q-Sets tend to represent the broad range of views held by a community, and therefore include statements that would engender strong disagreement. This is not considered to be a requirement, but some participants can find it difficult (and reported in this study) to sort statements with in a *forced-choice frequency distribution* along a continuum from 'most agree' to 'most disagree' (Figure 3).

Figure 12 forced-choice frequency distribution
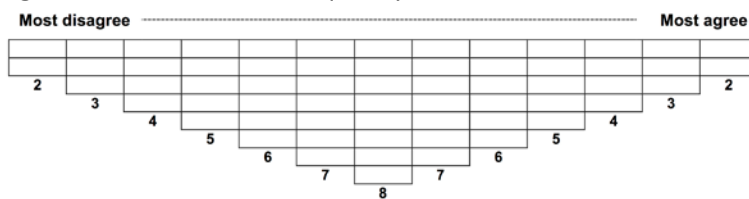
QSortWare (Pruneddu, 2014), an online Q-Sort survey tool, was used to capture responses from teacher educators across institutions in the United Kingdom. The sample is purposive (Guba, 1981) and was recruited through a design and technology teacher educator forum. The analysis of data was conducted using the PQMethod software (Schmolck, 2014).

Findings

There were 11 participating teacher educators (Figure 4) who responded to an invitation on a design and technology teacher educator email discussion group. The study continues to explore the subjective values or practitioner in relation to classroom practice.

Figure 13 Sample group (n=11)

Sorts	Main D&T specialism	Gender	Institution	ITE experience
1	Other	Male	Higher Education	More than 20 years
2	Graphic design	Female	Higher Education	10 to 20 years
3	Product design	Female	Higher Education	10 to 20 years
4	Other	Male	Higher Education	5 to 10 years
5	Graphic design	Female	Higher Education	5 to 10 years
6	Electronics and control	Male	Higher Education	5 to 10 years
7	Textiles and fashion	Female	Higher Education	10 to 20 years
8	Textiles and fashion	Female	School Direct	Less than 2 years
9	Product design	Female	Higher Education	More than 20 years
10	Electronics and control	Male	Higher Education	5 to 10 years
11	Electronics and	Male	Higher Education	More than 20

	control			years

Figure 14 Correlation matrix between Q Sorts

	1	2	3	4	5	6	7	8	9	10	11
1	100	40	26	53	22	24	27	16	18	-34	37
2	40	100	15	45	12	16	33	11	15	-33	45
3	26	15	100	29	25	31	1	20	30	-17	9
4	53	45	20	100	25	22	35	21	21	-35	59
5	22	12	25	25	100	23	0	12	15	-16	26
6	24	16	31	22	23	100	23	38	14	-41	32
7	27	33	1	35	0	23	100	-7	-6	-42	39
8	16	11	20	21	12	38	-7	100	25	-5	26
9	18	15	30	21	15	14	-6	25	100	-9	11
10	-34	-33	-17	-35	-16	-41	-42	-5	-9	100	-55
11	37	45	9	59	26	32	39	26	11	-55	100

Figure 5 shows the initial correlations between Q Sorts indicates correlations between the participants ranging from a positive 59 correlation between participants 4 and 11, to a negative 42 correlation between participants 7 and 10. Participant 10 shows a negative correlation to all other participants. This mirrors the findings of McLain et al (2015), acknowledging that there is "no 'one size fits all' approach" (p.272).

PQMethod initially extracted 8 factors, three of which had Eigenvalues (EV), or Kaiser-Guttmann criterion, above 1.00, indicating the statistical strength (Watts and Stenner, 2012, p. 105). Initially, factor one had an EV of 3.5994 and factor two 1.5627. Factor three, with an EV of 1.0299, was deselected prior to further analysis and factor rotation, Q Methodology experts tend to advise that one factor be extracted for every 6 to 8 participants (Watts and Stenner, 2012: 107). Figure 6 indicated the factor loadings for the each participant after the data was rotated.

Figure 15 Factor Matrix with an X Indicating a Defining Sort

	Loadings	
Sorts	1	2
1	-0.4489	0.5929 X
2	-0.2660	0.6944 X
3	-0.6 X	-0.0

	533	252
4	-0.4087	0.7064 X
5	-0.4829 X	0.1170
6	-0.2836	0.0636
7	0.2297	0.6701 X
8	-0.5187 X	-0.1445
9	-0.7156 X	-0.0025
10	0.0332	-0.5678 X
11	-0.2043	0.6772 X

% expl.Var.	19	24

A full table of the rankings of statements for each factor can be found in Figure 7, and are discussed below.

Consensus and distinguishing statements

Figure 7 indicated 30 consensus and 32 distinguishing statements between factors 1 and 2, with the Q-Sort Value (Q-SV) and Z-Score (Z-SCR) indicating the rank order and strength of agreement, respectively, for each.

Figure 16 Consensus Statements

Statement		Factor 1		Factor 2		Relevance	
		Q-SV	Z-SCR	Q-SV	Z-SCR	Cons.	Dist.
1	The teacher gives an overview of the content of the skills or knowledge being demonstrated ☐	4	1.31	4	1.45	✔	
2	The teacher uses technical language/terminology and key words	-4	-1.00	4	1.35		✔
3	The teacher presents their expectations	2	0.67	1	0.6	✔	
4	The teacher presents the learning objectives (knowledge/skills)	4	1.32	2	0.65	✔	

Statement		Factor 1		Factor 2		Relevance	
		Q-SV	Z-SCR	Q-SV	Z-SCR	Cons.	Dist.
5	The teacher presents the learning outcomes (i.e. what learners will do or be able to do as a result)	0	-0.15	5	1.57		✔
6	The teacher refers to the application, of what is being demonstrated outside the classroom context	-5	-1.4	-2	-0.81	✔	
7	The teacher demonstrates skills and knowledge that learners will apply within the lesson	-1	-0.41	2	0.61		✔
8	The teacher uses staged demonstrations, breaking down more complex process into separate (linked) demonstrations	-4	-1.08	4	1.38		✔
9	The teacher models/explains the whole process in one demonstration	6	2.06	-6	-2.09		✔
10	The teacher adapts their approach and style of demonstration to the learners, dependent on age, ability, prior experience, etc.	-5	-1.71	3	0.97		✔
11	The teacher gives clear verbal explanations of processes and procedures	-5	-1.33	6	1.96		✔
12	The teacher provides a running commentary through the demonstration	-3	-0.94	-1	-0.34	✔	
13	The teacher gives clear models/examples processes and procedures	2	0.53	5	1.49		✔
14	The teacher makes reference to relationships with other related concepts (e.g. mathematical, scientific, technological, etc.)	-3	-0.8	-5	-1.31	✔	
15	The teacher make reference to cause and effect of decisions and/or actions	-2	-0.73	-4	-1.17	✔	
16	The teacher uses examples, analogies and/or similes to explain processes and procedures	-2	-0.62	-2	-0.68	✔	
17	The teacher identifies the main points/steps for the learners	5	1.42	5	1.83	✔	
18	The teacher 'signposts' or indicates the next steps (i.e. "later in the lesson…" or "in next lesson…")	0	0.12	0	-0.12	✔	
19	The teacher models diagnostic processes, such as using testing equipment to fault-find or the application of scientific knowledge from an observation	4	1.41	-5	-1.23		✔
20	The teacher uses ICT to simulate or model process or products	6	2.34	-6	-2.18		✔
21	The teacher addresses learners misconceptions as they arise	-1	-0.34	1	0.42	✔	
22	As part of the planned demonstration, the teacher addresses common misconceptions around technical terms, concepts, etc.	-2	-0.59	1	0.25		✔
23	The teacher uses questioning to probe learners' prior knowledge from within the unit/project	1	0.19	1	0.37	✔	

Statement		Factor 1 Q-SV	Factor 1 Z-SCR	Factor 2 Q-SV	Factor 2 Z-SCR	Relevance Cons.	Relevance Dist.
24	The teacher questioning to probe learners' prior knowledge from previous D&T units/projects	-3	-0.75	1	0.44		✔
25	The teacher questioning to probe learners' prior knowledge from other subjects	-2	-0.6	-3	-0.93	✔	
26	The teacher uses questioning to enable learners to recall aspects of the process demonstrated	1	0.42	2	0.63	✔	
27	The teacher uses questioning to probe understanding of concepts, process and procedures	-6	-2.34	2	0.73		✔
28	The teacher uses questioning to encourage learners to speculate (e.g. predicting the next step in a process)	-4	-1.12	-1	-0.55	✔	
29	The teacher uses visual resources, such as images, photographs and diagrams, to enhance their demonstrations	0	-0.07	-5	-1.43		✔
30	The teacher prepares and uses examples of the products/outcomes being demonstrated	1	0.37	0	-0.27	✔	
31	The teacher prepares examples showing the steps/stages of the process being demonstrated	1	0.14	0	-0.07	✔	
32	The teacher prepares the demonstration station/area in advance (e.g. before the lesson)	1	0.32	2	0.72	✔	
33	The teacher uses resources, such as instruction sheets, slideshows or videos, after the demonstration to support learners	1	0.36	-2	-0.59		✔
34	The teacher uses other support staff (i.e. technician or teaching assistant) during, and after, the demonstration to support learners	5	1.90	-1	-0.54		✔
35	The teacher identifies hazards and risks for the learners	3	0.77	4	1.12	✔	
36	The teacher prompts learners to identify hazards and risks for themselves	0	-0.28	0	-0.13	✔	
37	The teacher is competent to use equipment safely	-6	-2.57	6	2		✔
38	Appropriate information about risk is readily available to learners	3	0.91	1	0.6	✔	
39	The teacher sets high standards and expectations for the learners in designing and making activities	-2	-0.7	0	-0.2	✔	
40	The teacher identifies alternative actions or choices learners can or need to do (e.g. design, make, evaluate)	3	1.28	-4	-1.22		✔
41	The teacher enables learners to identify alternative actions or choices that they can make (e.g. design, make, evaluate, etc.)	-1	-0.43	-4	-1.13	✔	
42	The teacher plans and uses extension or enrichment activities for able learners	1	0.47	-1	-0.47		✔

Statement		Factor 1 Q-SV	Factor 1 Z-SCR	Factor 2 Q-SV	Factor 2 Z-SCR	Relevance Cons.	Relevance Dist.
43	The teacher encourages/supports learners to demonstrate skills and knowledge to their peers	0	0.13	-2	-0.69		✔
44	The teacher encourages learners to participate in fault finding and quality control	-1	-0.41	-2	-0.65	✔	
45	The teacher ensures that they make eye contact with members of the whole group	2	0.70	-1	-0.45		✔
46	The teacher scans and monitors the group, as they are teaching, to ensure that the learners are engaged	-3	-0.99	1	0.16		✔
47	The teacher scans and monitors the group to ensure that learners are safe	-3	-0.79	3	1.01		✔
48	The teacher has 'presence' within the classroom	3	0.72	-1	-0.34		✔
49	The teacher can modify their tone when talking to/with different sized groups and in different situations	5	1.46	0	-0.18		✔
50	The teacher encourages learners to 'think-out-loud' to consolidate knowledge and understanding	3	0.76	-3	-0.99		✔
51	The teacher explains the function and/or context of the matter (i.e. knowledge and/or skill) being demonstrated	0	0.13	-3	-0.84		✔
52	The teacher encourages learners to reflect on values (e.g. the impact of a technology on society, the environment, etc.)	-2	-0.5	-3	-1.09	✔	
53	The teacher scans the room after the demonstration to monitor learners' progress	2	0.54	0	0.14	✔	
54	The teacher waits for learners to attempt a task before intervening	-1	-0.3	-3	-0.94	✔	
55	The teacher encourages learners to support each other before seeking the assistance of the teacher	3	0.75	-4	-1.16		✔
56	After the demonstration, the teacher moves around the room to support learners	2	0.54	0	0.02	✔	
57	The teacher shows/explains the process/skill to individuals who have misunderstood processes or concepts shortly after a demonstration	0	0.11	-2	-0.75		✔
58	The teacher uses questioning to ascertain what a learner understands, when they have not fully understood the demonstration	-1	-0.41	2	0.76		✔
59	The teacher explains what learners are expected to do to make progress	0	0.00	3	1.04		✔
60	The teacher makes his/her expectations of the learners' outcomes clear	2	0.54	3	1.03	✔	
61	The teacher provides examples of outcomes of a process that exemplify the skills being modelled	-4	-1.04	-1	-0.57	✔	

Statement		Factor 1		Factor 2		Relevance	
		Q-SV	Z-SCR	Q-SV	Z-SCR	Cons.	Dist.
62	The teacher ensures that all learners know what they need to do to make progress	-1	-0.30	3	0.81		✔

Discussion

The factors extracted represent two distinct groups of participants (factors) with similar trends in their responses, discussed below, focusing on the higher ranked statements. Figure 7

Factor 1: the teacher as a manager of the learning environment

Factor 1 is comprised of 4 teacher educators; all are female, with two identifying their main specialism as product design, one as graphic design and one as textiles and fashion.

The top responses indicate that the members of this group value didactic approaches through a planned and structured learning experience, where the knowledge is broken down into its components parts (17:5), modelling and explaining a process in one demonstration (9:6), supported by ICT to stimulate or support understanding of a process or product (20:6). The teacher should consider pedagogical approaches by differentiating for learners through support from other adults in the classroom (34:5), and modification of their approach in response to different groups and situations (49:5).

Also valued are clear expectations of learning and progress (1:4, 4:4, 3:2, 60:2), including "…models/examples processes…" (13:2); wider application of the knowledge being demonstrated, but recognising the role of the learner through peer support (55:3), consideration of how the knowledge can and will be applied in other contexts (40:4) and encouraging learners to speculate and synthesis knowledge (50:3). In addition, they identify classroom management, through safe use of equipment (37:3), identifying (35:3) and providing information about hazards and risks for learners (38:3), and whole class presence (48:3), awareness through visually scanning the room, during (45:2) and after (53:2) demonstrations, and moving "around the room to support learners" (60:2). This demonstrates a range of pedagogical and contextual knowledge in the planning and delivery.

Factor 2: the teacher as the mediator of knowledge

Factor 2 is comprised of 6 teacher educators (4 male and two female), with two identifying their main specialism as electronics and control, one as graphic design, one as textiles and fashion, and two as 'other', which may indicate either multiple specialism or one that was not listed as an option, such as engineering or resistant materials.

This group of teacher educators also value didactic approaches through a planned and structured demonstration, but the response focus on the learning outcomes (5:5), identification of the main points or steps (17:5) and use of clear models and examples (13:5) of processes and procedures, underpinned by clear verbal explanations (11:6).

The didactic focus is further emphasised through the importance placed on the teacher providing an overview of the skills or knowledge being demonstrated (1:4), in common with Factor 1, linking to learning and made clear through expectations of outcomes (60:4), what learners need to do (59:3) and the teachers role to enable them (62:3) to make progress. In contrast with Factor 1, the group of teacher educators in Factor 2 consider the breaking down of more complex process into separate, staged demonstrations (8:4), and the use of technical language and terminology (2:4) to be important, alongside demonstrating knowledge and skill in the context of the lesson in which it will be applied (7:2).

Factor 2 identify pedagogical dimensions in differentiation of approaches to the learners (10:3) and the use of questioning for recall (26:2) and probing understanding following a demonstration (58:2) and of concepts, process and procedures (27:2); highlighting an adaptive approach which is underpinned by teachers' pedagogical and subject knowledge.

In common with Factors 1, Factor 2 values the importance of learning objectives (4:2) and outcomes (60:3), identification of hazards and risks (35:4) and previewing content of a demonstration (1:4). Similar themes also emerge through other statements, including preparation (32:2), management of risk through identification of hazards (35:4), scanning and monitoring for learners' safety (47:3).

Comparing Factors 1 and 2

The teacher educators, in both factors, broadly agree on the role of didactic and pedagogic approaches. In this context, didactic relates to theory of teaching and specifically how subject knowledge is composed, reflected in how concepts or processes are broken down into main points, steps or stages. The teacher educators in Factor 2 extend the didactic theme to a process being staged in separate demonstrations (8:4), which Factor 1 do not consider to be as important (8:-4).

Both factors highlight pedagogical approaches, emphasising learning, with Factor 1 considering speculation and Factor 2 favouring questioning. Similarly, both value the skill of the teacher to differentiate, although Factor 1 ranks this higher than Factor 2

Conclusion

This study continues to explore the beliefs of the design and technology community in relation to teacher modelling and explaining. The participants broadly agree that a demonstration draws on didactic and pedagogic knowledge. In agreement with the teachers in McLain et al (2015), the teacher educators placed higher value on the teacher's engagement with procedural and strategic knowledge, although they did not hold that the teacher be "competent to use equipment safely" (statement 37) to be the highest ranked item. Figure 8 shows the top 10 consensus statements for the teacher educators in this study (with the average Q-Sort Value). These reinforce the role of didactics, in the teacher's ability to break down subject knowledge and present expectations, objectives and outcomes. Items indicate with an asterisk (*) feature in the top 10 statements for teachers in McLain et al (2015). Where the teacher educators differ to the teachers, in McLain et al, relate to the pedagogical role of the teacher to facilitate learning through questioning.

Figure 17 Top 10 consensus statements

No.	Ave.	Statement
*17	5.0	The teacher identifies the main points/steps for the learners.
*1	4.0	The teacher gives an overview of the content of the skills or knowledge being demonstrated.
35	3.5	The teacher identifies hazards and risks for the learners.
4	3.0	The teacher presents the learning objectives (knowledge/skills).
*60	2.5	The teacher makes his/her expectations of the learners' outcomes clear.
38	2	Appropriate information about risk is readily available to learners.
3	1.5	The teacher presents their expectations.
26	1.5	The teacher uses questioning to enable learners to recall aspects of the process demonstrated.
*32	1.5	The teacher prepares the demonstration station/area in advance (e.g. before the lesson).
23	1.0	The teacher uses questioning to probe learners' prior knowledge from within the unit/project.

References

Andersen, L.W. and Krathwohl, D.R. (eds) (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Addison Wesley Longman.

Bloom, B.S. et al (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals: Handbook 1, Cognitive Domain.* New York: Longman Higher Education.

Claxton, G., Lucas, B. and Webster, R. (2010a). *Mind the Gap: research and reality in practical and vocational education.* London: Edge Foundation

Claxton, G., Lucas, B. and Webster, R. (2010b). *Bodies of Knowledge: how the learning sciences could transform practical and vocational education*. London: Edge Foundation

Dave, R. (1967). *Psychomotor domain.* Berlin: International Conference of Educational Testing.

Dewey, J. (1916). *Democracy and Education by John Dewey*. Hazleton, USA: Pennsylvania State University.

DES and WO (1988). *National Curriculum Design and Technology Working Group: Interim Report*. London: Department for Education and Science/Welsh Office.

DFE (2016). Educational Excellence Everywhere [online]. Available at https://www.gov.uk/government/publications/educational-excellence-everywhere [last accessed 15 May 2016]

DFE (2011). *The Framework for the National Curriculum. A report by the Expert Panel for the National Curriculum review* [online]. Available at: https://www.gov.uk/government/publications/framework-for-the-national-curriculum-a-report-by-the-expert-panel-for-the-national-curriculum-review [last accessed 15th May 2015]

Fuller, A. and Unwin, L. (2003). Learning as apprentices in the contemporary UK workplace: creating and managing expansive and restrictive learning environments, *Journal of Education and Work*, 16(4), p.406-427.

Froebel, F.W. (1900). *Pedagogics of the Kindergarten*, trans. J. Jarvis, New York: D.Appleton,

Guba, E.G. (1981). Criteria for Assessing the Trustworthiness of Naturalistic Inquiries. *Educational Communication and Technology,* 29(2), pp. 75-91. Available at: http://www.jstor.org/stable/30219811 [last accessed 12 April 2014]

Harrow, A.J. (1972). *A taxonomy of the psychomotor domain.* New York: David McKay Co.

Marranzo, R.J. and Kendell, J.S. (2007). *The New Taxonomy of Educational Objectives 2nd Edition*. London: Sage Publications Ltd.

McLain, M., Barlex, D., Bell, D. and Hardy, A. (2015). Teacher perspectives on pedagogical modelling and explaining in design & technology: a Q Methodology study. In: Marjolaine Chatoney. *Plurality and Complementarity of Approaches in Design and Technology Education.* April 2015, Marseille, France. 2015 [available at: https://hal.archives-ouvertes.fr/hal-01161553]

McLain, M., Bell. D. and Pratt, A. (2013). Show-how know-how (Part 1): Theory and practice for demonstrating in Design and Technology. *D&T Practice*, 3/2013. Wellesbourne, UK: Design and Technology Association.

Milne, C. and Otieno, T. (2007). Understanding engagement: Science demonstrations and emotional energy. Science Education, 91(4), July 2007. Available at: http://dx.doi.org/10.1002/sce.20203

Mosston, M., and Ashworth, S. (2002). *Teaching Physical Education (fifth edition).* San Francisco: Pearson Education Inc.

NCC (1990). *Technology in the National Curriculum*. London: Department for Education and Science and the Welsh Office.

Petrina, S. (2007). *Advanced Teaching Methods for the Technology Classroom*. London: Information Science Publishing.

Pruneddu, A. (2014). *QSortWare* [Online software]. Available at http://www.qsortouch.com (Accessed October 2014)

Schmolck, P. (2014). *PQPethod (Version 2.35)* [Computer program]. Available at http://schmolck.userweb.mwn.de/qmethod/index.htm (Accessed October 2014)

Simpson E. J. (1972). *The Classification of Educational Objectives in the Psychomotor Domain.* Washington, DC: Gryphon House.

Watts, S. and Stenner, P. (2012). *Doing Q Methodological Research: theory, method and interpretation*. London: Sage Publications Ltd.

The pedagogical theories of the Exploratory Production Model

Mika Metsärinne[1] and Manne Kallio[2]
[1] University of Turku, Faculty of Education, Department of Teacher Education
Rauma, Finland
mika.metsarinne@utu.fi
[2] University of Helsinki, Faculty of Behavioural Sciences, Department of
Teacher Education,
University of Helsinki, Finland
manne.kallio@helsinki.fi

Abstract

The purpose of this paper is to examine the pedagogical theories of the Exploratory Production Model (EPM). The model is used as a central approach in learning and teaching in Design and Technology Education. We first present the model's pedagogical theories: *Envision Learning, Project Learning, Problem Based Learning, Process Learning and Model Learning*. When following the theories, the role of the learner changes, step by step, from being a receiver of the teacher's guidance to being a self-directed explorer of her/his own production activities. Ultimately, the theory of Envision Learning challenges learners to set unique goals for all their production activities while, in contrast, Model Learning is similar to extrinsically motivated instrumental learning.

Secondly, the four most learner-centred pedagogical theories are described through examples from the teacher practice of master's-level students in Design and Technology Education. The descriptions are based on the students' portfolios and the feedback from schools. The cases reveal that the higher the learner-centred theory the teacher uses is, the more multifaceted is the learning. Moreover, the learning is more intrinsic motivated and thereby deeper regarding to the learners' own life-world. Varying between the different theories helps teachers to organize the classroom techniques and motivate learners in meaningful learning and cooperation. The pedagogical theories are applicable in differentiating teaching and learning between different groups and between the learners within a certain group.

Keywords: Pedagogical Theories, Learning, Teaching, Exploratory Production

Introduction

Citizenship in the 21th century requires everyone to be aware of the risks and the potential of technologies. Everyone should have the capability to explore the environment of life and enhance it with technology. The problem of teaching technological production activities, however, is that whilst there is very good reason for us to draw up a list of qualities that are important in Design and Technology Education, such lists tend towards atomization rather than holism (Kimbell, 2009, 5). The learning tasks designed by the teachers are not enough for learners' thoughtful technological thinking. Although such learning tasks might be related to interesting scientific phenomena with important Technology Education content, they might not relate to the life-world phenomena of the

learner's real personal risks and potential. Such motivation is required in meaningful exploratory production activities. The conclusion is that the goals of learning and production should be balanced between learner-centred goals and the general goals presented by the teacher. Finally, the learner's imagination represents the real life-world while the visual presentation of the teacher is an image.

The utilities of the learner-centred goals and the general goals are combined in the pedagogical theories of the Exploratory Production Model (EPM). In this paper, these theories are examined in the teacher practice of master's-level Technology Education students in Finland. The research question is as follows: How do the teacher trainees use the pedagogical theories? Altogether, the students have three training periods. The study focuses on the final one, in which the trainees are expected to construct their own usage theory on the elements of the pedagogical theories. This training period takes place in 8th and 9th grade classes.

Theoretical background

In Finland, the main focus of Technology Education is on learners' production activities. Learners' innovativeness and self-directedness is taught following the Exploratory Production Model (Metsärinne, Kallio & Virta, 2015; Kallio & Metsärinne, 2016; comp. Zimmerman's Model of Self-Regulated Learning (SRL) 1998, 4; 2011, 56). Exploratory Production has a philosophical basis that includes an existential (Peltonen, 2003; Collin, 1985; Heidegger, 1967) and situational viewpoint (Dewey, 2012, 118–126; 1938b, 66). Learners are educated to set goals for their learning and to monitor, regulate and control their cognition, motivation and behaviour, guided and constrained by their goals and the contextual features of the environment. Each learning task with a unique production case renews the learner's knowledge base, which has an effect on the next task and case (Kallio & Metsärinne, 2016).

In the Definition Phase of the Exploratory Production Model, a learner defines goals for forthcoming technological production activities. The Implementation Phase that follows is regulated by the quality goals set in the Definition Phase. The profile of the quality preconditions for the implementation (ideation, planning and manufacturing) are defined in the Definition Phase. The Reliability and Quality Control Phase includes testing the goals set for the production and qualities of the product, assessing learning outcomes, and self-evaluation. Returning paths are addressed according to the goals defined for the entire production activity. Testing the novel technological product is linked to testing the quality profile of learning through the entire production activity. As the product indicates case-specific qualities, the learning outcomes indicate the individual growth of the learner's technological capability. The integrated model of Exploratory Production and the pedagogical theories combine the utilities of production activities and learning.
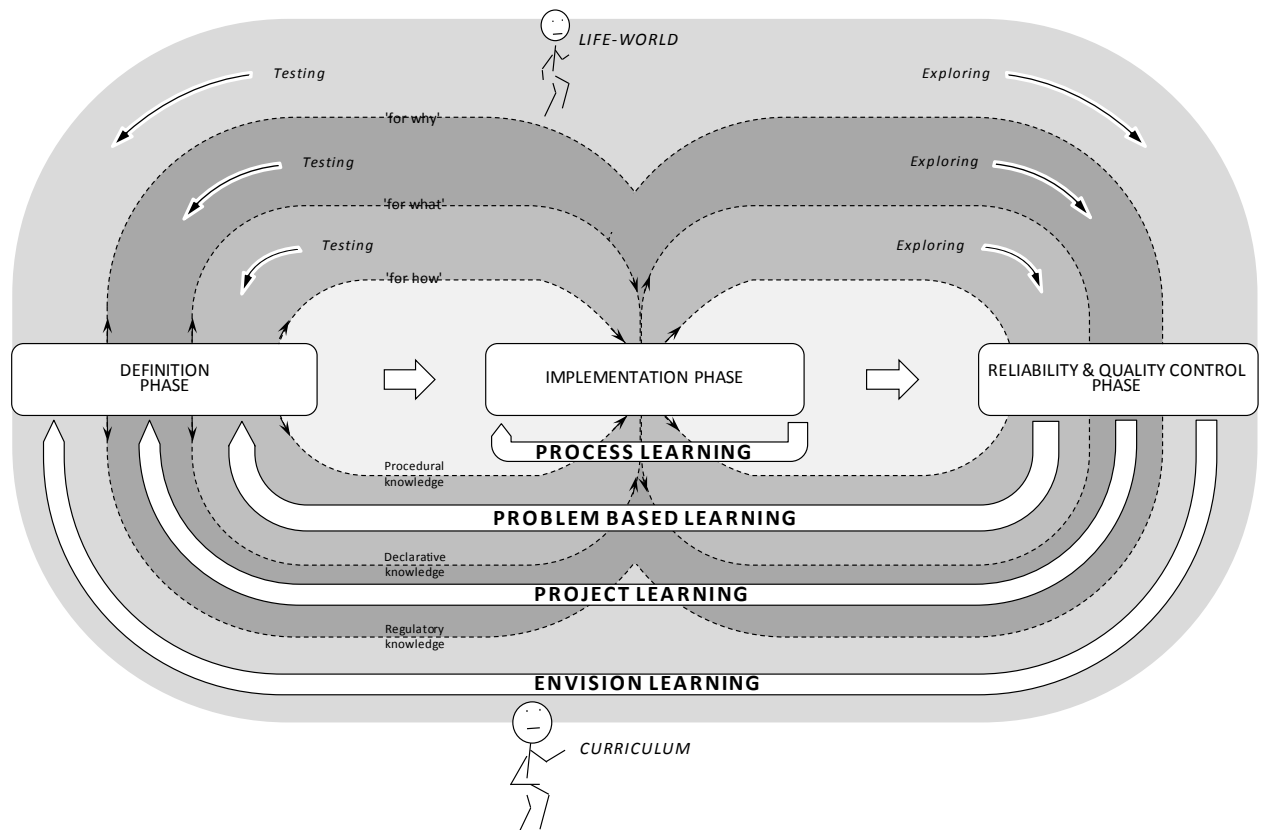
Figure 1. The pedagogical theories of the Exploratory Production Model

Envision Learning

In Envision Learning, the learners are allowed to define the goals for their production activities individually. Thus the regulatory knowledge, in which the ideation, designing and constructing of the product are based on, is entirely the learner's own. In the Definition Phase, the teacher's role is to stimulate the learner's thinking in exploring the values and risks of their life-world in order to enhance it. The learner is expected to answer why she/he is undertaking the forthcoming technological production activities and learning. During the Implementation Phase, the teacher supports the learner in examining the content and processes.

Project Learning

Adopting the classification of William Kilpatrick (1918, 332–334), the originator of the Project Method, the projects of the 1st category are intentional productive processes with anticipated goals; that is to say, in Technology Education projects new technologies are produced intentionally. The Exploratory Production procedure is comparable to the Project Method, as it consists of goal setting, designing, implementing and evaluating the outcomes. Unlike Envision Learning, the teacher presents the learner with a predefined theme; however, the theme must not refer to certain products or techniques. The teacher guides the learner in exploring technological knowledge in order to define the quality profile for the production and learning. Furthermore, the teacher supports the learner in the product ideation, design and construction during the Implementation Phase.

Problem Based Learning

At the beginning of Problem Based Learning the teacher presents the learner with a problem related to the forthcoming technological production activities. Solving the nominated

problem is a case of production in Problem Based Learning; however, there are many minor problems to solve all the way through any technological production activity. Unlike Envision Learning and Project Learning, the problem is now set by the teacher, instead of the learner being expected to define the problem by him/herself. The learning task is therefore more limited, and the learning and production are directed more by the teacher. The teacher guides the learner to explore problem-solving methods as well as analogies to other relevant problems in order to find a technological solution. The quality profile of the learning and production is already predefined, for the most part. Hence the learner is able to proceed to the Implementation Phase quite soon.

Process Learning

In Process Learning the teacher has predefined the quality profile for learning and production, while in higher learning theories the quality profile is defined more by the learner. However, the learner might have certain personal goals as well. The teacher guides the learner in exploring and applying the technological knowledge of the content and processes. The selection of technologies, techniques and materials is more limited, so the learning and production are directed towards certain objectives. The learner still has important decisions to make and problems to solve during the design and construction process.

Model Learning

Model Learning means acquiring certain technological knowledge and teaching to use certain technologies or techniques. Furthermore, it might mean constructing a certain product or putting a predefined design process into practice.

Method

In the master's-level teacher practice period the trainees are taking their first steps in constructing their own usage theory of teaching. The students are reflecting on the knowledge and practice of Technology Education. At the beginning of the practice period the trainee composes the learning task for the learners, with the general goals conforming to the National Core Curriculum and local curriculums. The trainees are expected to become oriented to the pedagogical theories, the models of technological production activities, exploratory teachership and the interaction between the teacher and the learners. The focus of this study is on the pedagogical issues related to the Exploratory Production Model.

The data consist of randomly selected portfolios and feedback reports from the supervisors (n = 100) of master's-level teacher trainee practice (years 2008–2013) in 8th and 9th grade Technology Education. In the trainees' instructions for their portfolios it is stated: "In the end of the training period, the trainee must assess each pupil of the group." Moreover: "A pupils' present self-evaluation." They were classified using theoretical content analysis based on the pedagogical theories of the Exploratory Model. Furthermore, one case from each class, Model Learning excluded, was selected for more detailed analysis.

Table 1. The cases and the examples of the learning tasks.

Learning theory	Cases (n)	Examples of the learning tasks
Envision Learning	12	'Produce a technological product to enhance the environment of life' 'Cultural heritage'
Project Learning	29	' Local cultural heritage' 'Technology as a hobby' 'Transporting a thing with a bicycle'
Problem Based Learning	31	'Holding a certain thing' 'Lifting a heavy object' 'An electric vehicle'
Process Learning	21	'Embedded electric control' 'A certain musical instrument' 'Etching a copper plate'
Model Learning	7	'Marquetry technique' 'Servicing a bike or a moped' 'Four-stroke engine'

Results

First, the results revealed that all of the pedagogical theories were used in the teacher practice periods. However, Model Learning was used only in seven of the one hundred cases analysed. Model Learning was used in some teacher-directed cases with the goal of acquiring very special technological knowledge or learning certain practices. On the other hand, learners also implemented very special technological solutions in the learner-centred cases when Envision and Project Learning were engaged in. The theories of Model and Process Learning were used when the goal was to learn new technological content, while Envision and Project Learning theories were used when the goal was to explore solutions for more complicated production activities. The theory of Problem Based Learning was used when both learning and production was the preferred goal. Nevertheless, the higher the pedagogical theory that was used, the more thoughtful was the learning and more complicated the production. Collaborative learning methods were used more in Project and Problem Based Learning, while more independent work was preferred in Envision and Process Learning. The relation between the learning task and the examples of the technologies reveal how multifaceted the learning is.

Table 2. The description of the selected cases (n = 4).

Learning Theory	General goal	Learning task	Examples of the technologies
#1 Envision Learning	Intrinsic motivation Attitudes Self-regulated learning Self-assessment Exploring the life-world	*'Produce a technological product to enhance the environment of life'*	Audio system for a moped car Thoughtful learning of certain techniques or acquiring of technological knowledge Furnishing and decorating at home
#2 Project Learning	Innovativeness Exploring scientific knowledge Developing technological solutions	*'A technology as a hobby'* The students were expected to acquaint themselves with the predefined theme.	Various holders and carrying devices for sports Different musical instruments
#3 Problem Based Learning	Ideation Problem solving Exploring phenomena mathematics and physics	*'A problem of lifting objects'* The students were expected to explore a solution and implement it in a miniature model.	Various cranes and elevators
#4 Process Learning	Acquiring technological knowledge and learning certain practices Design skills	*'A light or a lamp'* The students learned the principles and practice of producing a circuit board and CNC milling machine based on the implemented technology	Various lights and lamps in which the predefined materials or techniques were used

Case #1: Envision Learning

The trainee paid special attention to awakening the learners' intrinsic motivation and attitudes in technological thinking and production activities. The trainee presented the learners with different sources of knowledge and personally talked to each learner as well as small groups. The trainee had time for this since no general content or practices needed to be taught at the same time. As the learners' own goals were preferred, the assessment of the outcomes was clear. In the Implementation Phase, the assessment focused on the predefined quality profiles set by the learners themselves but not on the technical performance. However, testing the learners' newly produced technologies was quite complicated because they all had different purposes related to the learners' homes, leisure time activities, and so on.

Case #2: Project Learning

Since all learners had the same theme, the collaboration in small groups was fruitful. The trainee could direct the learners in exploring knowledge for their projects, hence the

learners were able to go straight ahead and start composing the quality profile for their projects. The learners were expected to explore the theme thoughtfully before proceeding to the Implementation Phase and begin the ideation. The trainee emphasized that no products should be ideated before the expected qualities were defined. This was important in order to make the ideation meaningful and innovative, since beginning with a predefined product idea leads to a casual solution and underachievement. The learners, for example, compared their own criteria to the criteria of other learners, as well as the previous well-known solutions, and this also made the assessment more interesting in the end. Once the product ideation was under way, the trainee presented the learners with various possible techniques and technologies to increase the potential of the learners'.

Case #3: Problem Based Learning

The first lesson began by presenting the learners with a problem for which a technological solution was expected. Since the problem was to lift objects, it was related to mathematics and physics. The learners were directed to explore knowledge about, for example, transmissions, pneumatics, hydraulics, pulley tackles and the strength of constructions, collaboratively in small groups. Since the quality profile of the solution was predefined, the learners were able to proceed quite quickly in to the ideation of the solution. The assessment focused on comparing the predefined quality profile to the test results of the solution, like a crane, constructed by the learners. This kind of assessment seemed to motivate the learners because it was clearly comparable between the groups; however, the situation made the groups compete with one another.

Case #4: Process Learning

The acquiring of certain technological knowledge and the learning of practices were highlighted when following the theory of Process Learning. The trainee presented the learners with relatively closed learning tasks with the clear quality profiles of a light or a lamp. The learners were expected to design and construct their solutions primarily using certain techniques and materials. Even though the learners followed certain technological processes, the design of the lamps varied widely. More systematic progress during the process was easier for learners who felt it difficult to ideate and explore new areas of interest and knowledge. Unlike in the higher learning theories, the focus of the assessment was more on the procedural matters than on self-regulated learning or innovativeness.

Discussion

The results reveal that the higher the learner-centred theory used by the teacher, the more multifaceted the learning is. Moreover, the learning is more intrinsic motivated and thereby deeper, regarding to the learners' own life-world. Varying between the different theories helps teachers to organize the classroom techniques and motivate learners in meaningful learning and collaboration. The pedagogical theories are applicable in differentiating teaching and learning between different groups and between the learners within certain groups. In several cases the trainees used different learning theories for some of the learners within a particular group. While the majority of the learners followed Project Learning, some of the learners with difficulties in interaction skills, concentration, or attitudes, for instance, were given a Process Learning task or even a Model Learning one. As well, when a Problem Based learning task was followed, for

example, some learners with strong intrinsic motivation were allowed to envision their own technological production activities.

The pedagogical theories of the Exploratory Production Model were used in a versatile way. Envision Learning was not used as often as the other theories, and Model Learning was used only rarely. These are the two ultimate contradistinctive theories of learning. Envision Learning challenges learners to regulate their unique goals for all technological learning and production activities while Model Learning is like extrinsically motivated instrumental learning. The acquiring of Procedural Knowledge is highlighted in Process Learning while Declarative Knowledge is focused more on Problem Based Learning. The higher the learning theory is, the more learner-centred is the learning. Moreover, the learning is more intrinsically motivated, self-regulated, and the focus is on the goals set by the learner. Envision Learning is based on the phenomena of the learner's own life-world and the enhancement of it with technological production activities. The learning of technological processes or content might remain more narrow but nonetheless thoughtful. However, as the learners are expected to be more responsible for their learning and production when following the higher learning theories, some learners might become frustrated. When moving to the higher theories, the role of the learner changes, step by step, from being a receiver of the teacher's guidance to being a self-directed explorer of her/his own technological production activities.

The emphasis on learner-centred technological production activities (Regulatory Knowledge, of 'why') or on the teacher-directed learning of technological knowledge and processes (Declarative Knowledge, of 'what', and Procedural Knowledge, of 'how') differs between cultures and over time. According to the 21th-century conception of these dimensions, learning is a learner-centred exploration and enhancement of the life-world rather than a teacher-directed illustration of the phenomena of the sciences. However, knowledge of the laws of nature and principles of technologies are needed in Exploratory Production learning. Regulatory Knowledge is required to control Declarative and Procedural Knowledge. The final conclusion is that all of the pedagogical theories are required when aiming to implement the Envision Learning theory of the Exploratory Production Model.

References

Curedale, R. (2013). *Design Thinking. Process and methods manual.* Design Community College Inc. USA.

Collin, F. (1985). *Theory and Understanding*. *A Critique of Interpretive Social Science*. New York: Basil Blackwell.

Dewey, J. (1938). *Logic. The Theory of Inquiry*. UK: Milton Keynes.

Dewey, J. (2012). *Filosofian uudistaminen (orig. Reconstruction in Philosophy, first published in 1920).* Tampere: Vastapaino.

Heidegger, M. (1967). *Sein und zeit.* Tübingen: Max Niemeyer Verlag.

Kallio, M. (2014) *Risk-Responsibility in Safety Education Culture*. Annales Universitatis Turkuensis C382.

Kallio, M., & Metsärinne, M. (2015). How Do Different Background Variables Predict Learning Outcomes? *International Journal of Technology and Design Education.* 10.1007/s10798-015-9339-7

Kilpatrick, W. H. (1918). *The project method.* Teachers College Record, Vol. XIX, no. 4, 319-335.

Kimbell, R. (1994). 'Tasks in Technology: An Analysis of their Purposes and Effects'. *International Journal of Technology and Design Education 4*, 241-256.

Kimbell, R. (2009). Holism and the Challenge of Teachers' Judgement. *Design and Technology Education: An International Journal 14*(1), 5-6.

Metsärinne, M. (2004). Project Based Sloyd. *Techne Series A 6*.

Metsärinne, M., & Kallio, M. (2015). How are Students Attitudes related to their Learning Outcomes? *International Journal of Technology and Design Education.* 10.1007/s10798-015-9317-0

Metsärinne, M., Kallio, M., & Virta, K. (2015). Pupils' Readiness for Self-Regulated Learning in the Forethought Phase of Exploratory Production. *International Journal of Technology and Design Education 25* (1), 85-108. 10.1007/s10798-014-9273-0

Metsärinne, M. (2011). Examining Process Learning of Technology by Basic and Sample Assessment. In: S. Laitinen & A. Hilmola (eds.) *Learning Results in Craft – An Expert Analysis.* Finnish National Board of Education, Reports 2011:11, 194–206.

Peltonen, J. 2003. The Chain of Rational Theories as the Directing Means of Productive Activities in Academic Sloyd Education. In: K. Virta (ed.) Current Research on Sloyd Education. *Techne Series A 5*, 78–96.

Zimmerman, B. J. 1998. Developing Self-Fulfilling Cycles of Academic Regulation: An Analysis of Exemplary Instructional Models. In: D. H. Schunk & B. J. Zimmerman (eds.) *Self-Regulated Learning From Teaching to Self-Reflective Practice.* (pp. 1–19) New York & London: The Guilford Press.

Zimmerman, B. J. 2011. Motivational Sources and Outcomes of Self-Regulated Learning and Performance. In: B. J. Zimmerman & D. H. Schunk (eds.) *Handbook of Self-Regulation of Learning and Performance.* (pp. 49–64)*.* Routledge.

Female technical craft teachers in a key role in developing Finnish technology education

Sonja Niiranen
University of Jyväskylä
Finland
sonja.k.niiranen@jyu.fi

Abstract

Technology-oriented fields are still largely male-dominated, and an effective approach for increasing the number of women in technology and natural science careers has not yet been achieved in EU countries (She Figures, 2012). Technology education is relevant to the degree that it has the potential to develop students' skills in many ways by raising their awareness of the various dimensions of technology. In Finland, crafts and technology education in basic education will change soon when the new National core curriculum will come into effect in August 2016. Then crafts will become an integrated subject for girls and boys during compulsory lessons in grades one to seven.

This study investigates Finnish technology education, more specifically how to provide equal possibilities and support for girls to study it, through the eyes of female technology education teachers and teacher education students. The study was carried out using semi-structured questionnaires, and the data were collected from female technical craft teachers working in basic education schools and from female technology education and technical craft students in teacher education. A qualitative thematic analysis was carried out through the identification, coding, analysis and reporting of patterns within the data. This study presents suggestions on what should be done in order to increase girls' access to and interest in technology education based on female technology education teachers' and students' perspectives. It is hoped that these perspectives will facilitate the implementation of supportive interventions in the future.

Keywords: technology education, craft, girls, interests, basic education

Introduction

Whenever and wherever each of us was born and spent our early years, we have been profoundly influenced by the technologies we have encountered (Keirl, 2011, p. 237). Technology is an important part of our daily lives, and the experiences we have with technology have an impact on personal interests, career aspirations and social role patterns related to technology (Volk, 2007, p. 191). Technology education has been developed to help people with technology by providing them the tools and skills they need to understand and utilise it. It has a role in shaping future debates and discourses by developing technological literacy by encouraging critical thinking and by raising awareness of various dimensions of technology (Elshof, 2005). Technology education can also provide active engagement and participation, meaningful experiences and concrete representations of activity. It has been suggested that problem-based activities can assist

people to become critically literate to address issues through active engagement in both: tool-related hands-on and discursive practices of technology (Järvinen & Rasinen, 2015; Wilkinson & Bencze, 2011).

In Finland, there is no subject called technology education in basic education; rather, the education on the topic is currently decentralised and taught through various subjects (Autio, Hietanoro & Ruismäki, 2011; NCCBE 2004; NCCBE 2014). However, craft education, especially technical craft, can be seen as supporting technology education due to the fact that as early as 1866, Uno Cygnaeus described 'technological' content as an important aspect of craft education (Rasinen, Ikonen & Rissanen, 2006, p. 449). Since those times, boys have traditionally studied technical craft while girls have studied textile craft. Craft education in Finland is a practical subject with hands-on activities, and pupils actively practise experimentation, investigation, invention, problem solving and design skills. In craft education workshops (technical and textile), pupils are working with different materials and techniques when working with their projects.

Technology as a concept was only introduced – but not defined – for the first time in the Finnish Framework Curriculum for Comprehensive Schools in 1985 as a component of the craft subject, 'technical work and textile work' (Rasinen, Ikonen & Rissanen, 2011, p. 99). Finland's National Core Curriculum for Basic Education 2004 (NCCBE 2004), which is still in effect, introduced seven cross-curricular themes in Finnish education, one of which is 'Human beings and technology', that self-evidently addresses technology education. These themes should have the central emphasis in educational and teaching work and they should be included in studies of various subjects. However, it appears that much of the technological content of the 'Human beings and technology' theme is studied during crafts lessons, in particular technical craft and they share same specific aims (Järvinen & Rasinen, 2015).

Forthcoming new National Core Curriculum for Basic Education Finland

The NCCBE 2004 states that craft instruction should encompass core technical and textile content in grades one to seven. In addition, pupils may be given the chance, in their craft studies, to emphasize either technical or textile craft according to their interests and inclinations. Many schools in Finland still guide pupils to choose between technical and textile craft after grade four and exclude the other craft from their studies (Hilmola, 2015; Wakamoto, 2012). This depends on the school's policies; however, crafts, and therefore also technology education reveals a strong gender-related division. The division of crafts creates a situation whereby girls who study textile craft do not participate in technology-related activities that are part and parcel of technical craft studies. In fact, girls in grades seven to nine rarely choose to study technical craft, or even have the option to choose it anymore (Niiranen & Niiranen, 2015).

The guideline of Finland's new NCCBE 2014 is that craft should be an integrated subject for girls and boys during compulsory lessons in grades one to seven. The objectives dictate that it will not be possible to teach crafts based only on the contents of either technical craft or textile craft; rather, the contents of both crafts will be needed when the NCCBE 2014 is implemented. The main change from the NCCBE 2004 is the fact that the core contents of technical craft and textile craft will no longer be taught or referred to separately. Pupils' own interests in implementing craft education will be emphasised in the future, but the interpretation of this in practice remains to be seen when the new curriculum comes into effect in August 2016. This change is compatible with current

views of gender equality meaning that people can develop their abilities and make choices without gender related restrictions (Jakku-Sihvonen, 2013, p. 4).

Research question and methods

This study sought to investigate Finnish technology education, more specifically how to provide equal possibilities and support for girls to study it, through the eyes of female technology education teachers and teacher education students. The study was carried out using a semi-structured questionnaire, and the data were collected in 2015-2016. Potential participants were asked to participate in the study by email or through social media (Facebook group of technical craft teachers), and questionnaires were sent by email for those who agreed. The study group consisted of seven female technical craft and technology education teachers who graduated from various universities in Finland and eight female teacher education students who specialise in technical craft and technology education. The teachers worked in schools of basic education and taught technical craft and technology education for pupils at grades 3–9 (ages 9–15). Three of the teachers were primary school teachers and four of them worked in secondary-level schools. All of them had studied at least 25 European Credit Transfer and Accumulation System (ECTS) units of technical craft and technology education in university. The teacher education students were 24–31 years old and have been studying for at least four years at the university. All participating students were still studying or have recently graduated from the Department of Teacher Education, University of Jyväskylä.

The semi-structured questionnaire consisted of questions concerning background information and whether participants had studied either technical craft or textile craft or both in school in grades four to nine, and for how long. Then participants were asked to reflect freely on the following themes: 'What kind of issues have an effect on girls' interests towards technical craft and technology education?'; 'What do you think about the division in craft, between technical and textile craft in schools and how would you organise crafts in the future at grades 1–7 and 8–9?'; 'What do you think about the relation of technical craft studies in school to, and its affect on, a woman's interest in entering technology-oriented field?' The data were analysed by using a qualitative content analysis. This type of analysis was chosen because it is a suitable method for examining material with descriptive content, especially if the phenomenon being studied is relatively unknown (Schreier, 2012). When using qualitative content analysis in this study, the primary aim was to investigate and discover themes based on the frequency of their occurrence. Meaningful sentences or themes and manifest content were chosen as the analysis units. After coding, the analysis units were grouped and categorised.

Results

All 15 participants had studied technology in the form of technical craft to some extent during their basic education at grades 1–9. Two of the participants had chosen or had access to technical craft at grades 5–7, one had studied equal amount of both crafts (technical and textile craft) at grades 1–7 and one had studied a few courses of technical craft at grades 8–9. Most of the participants (12/15) has studied mainly textile craft at grades 5–7, and three of the participants had chosen to study textile craft also for grades 8–9 when it is an elective subject. This presents the gendered division that has been in technical and textile craft.
When participants were asked to reflect about the most influential elements that might have an effect on girls' interests towards technical craft and technology education,

almost all (12/15) presented the possibility to create meaningful, useful and motivating projects that would be connected with girls' everyday life. Moreover, some participants mentioned that girls in general are more concerned than boys about the decorative solutions of their products. Six of the participants also mentioned that girls' earlier experiences (i.e. received encouragement and role-models related to technical issues in the family) have an effect on girls' interests towards technical subjects. As one of them wrote 'I believe that earlier experiences, also lack of them, have an effect on girls' interests towards technical craft. When I was a child I did a lot of building and constructing activities with my father at home'. In addition, the teachers' attitudes, received encouragement and the influence of peers were mentioned in five participants' responses. Another identified element was the masculine image of technical craft by two of the participants, in the sense that 'girls should not study it'. However, in contrast, three of the participants presented that due to the fact that mainly boys are studying technical craft, some girls might choose to study it, especially if there is a female friend who would choose it also.

Participants were also asked about what they think about the still existing division in crafts, between technical and textile craft, in schools and how would they like craft education to be organised in the future at grades 1–7 and 8–9. Ten of the participants, seven of the students and three of the teachers, expressed that they would prefer craft education as a common, multi-material subject that should include both technical craft and textile craft for all pupils at grades 1–7. By then pupils would get an equal chance to experience both crafts and to freely develop their skills related to all of the contents and different materials without any gender-based traditions or expectations. In addition, eight of these participants hoped that the future craft education would be based more on project working by integrating various materials (multi-materiality) of technical and textile craft. Three of the participants thought that it would be better to let pupils to choose which craft to study for grades 6 and 7, in other words a few years later than the situation is in today's schools. Two expressed that they would keep the situation as it is now. Some of these participants, who thought that pupils should be able to choose which craft to study, stated that the risk of common craft education is that there would not be enough lessons for pupils to adequately study all the needed techniques. That leads to the situation that pupils will not get feelings of success in craft studies anymore. It was also stated that interests of girls and boys are different and they should be able to choose which craft to study.

In relation to technical craft studies in basic education and it's affect on women's interests in entering technology-oriented field, participants presented aspects that by technical craft studies girls can: 1) find their interests and self-esteem related to technology (10/15), 2) be provided with experiences, skills and knowledge that are needed in life (4/15), 3) be shown that technology is not only for males and be encouraged to enter technology-oriented fields (7/15).

The future of technology education in Finland

Based on various studies, it is evident that an increase in the number of women in technical careers has not yet been achieved in EU countries, and the reluctance of women to enter occupations in the natural sciences or technology is still a challenge that many educators confront all over the world (e.g. Klapwijk & Rommes, 2009; Mammes, 2004; Sander, 2012; She Figures, 2012). It has been claimed that Finnish basic education still demonstrates a very traditional image of gender roles to their pupils, because girls mainly

study textile craft with a female teacher, while boys study technical craft with a male teacher (Berg et al., 2011, p. 98; Kokko & Dillon, 2011; Niiranen & Niiranen, 2015). In order to introduce a more equitable gender balance in the higher education of technology-oriented fields and consequently in the labour market, I think it is highly relevant to continue to expand our knowledge of technology education and to give attention to gender related issues related to it already in basic education.

An interesting finding of this study was that many of the technical craft teachers and almost all of the teacher education students expressed that they would prefer future craft education as a common, multi-material subject that should include both technical craft and textile craft for all pupils at grades 1–7. They stated that girls can better find their interests and self-esteem related to technology through this and they can be provided with experiences, skills and knowledge that are needed later in life, and work life. They also expressed that an important factor of an equal technology education is that girls can be shown that technology is not only for boys and males. The change will happen in August 2016 when Finland's new NCCBE 2014 will come into effect. This development of crafts into an integrated subject for both girls and boys can be therefore seen as a positive change when thinking about girls' possibilities to study technology. However, providing girls with equal possibilities to study technology is only a start. Based on these participants' views, the most influential element in girls' interests towards technical craft and technology education would be the possibility to make meaningful, useful and motivating projects that would be connected with girls' everyday life. Therefore, activities during craft lessons should be planned and presented in such a way that all pupils would be interested in them and might see technology education as something valuable for them.

It has been stated that women's presence in technological fields is essential, because diversity fosters excellence in research and innovation (Gendered Innovations, 2013). As Kirsti Lonka, a professor of Educational Psychology said on 7th October 2015 at the Women in Tech forum, 'Embrace the difference and diversity between men and women. There is talent in everyone, gender doesn't matter if you master the skills.' (Lonka, 2015). Might the new form of craft education ultimately increase the number of female students who enter technology-oriented fields? Another related question is what role female technical craft and technology education teachers can have in this setting.

Summary

This study sought to investigate Finnish technology education, more specifically how to provide equal possibilities and support for girls to study it, through the eyes of female technology education teachers and teacher education students. It is evident based on the findings that future craft and technology education, should be an integrated, multi-material subject in Finnish basic education. It should also be developed towards gender-sensitive learning experiences and pupils should be offered the needed support and encouragement.

References:

Ardies, J. (2015). *Students' attitudes towards technology. A cross-sectional and longitudinal study in secondary education*. PhD dissertation. Antwerpen: Universiteit Antwerpen.

Autio, O., Hietanoro, J. & Ruismäki, H. (2011). Taking part in technology education: Elements in students' motivation. *International Journal of Technology and Design Education*, *21*(3), 349–361. doi:10.1007/s10798-010-9124-6

Berg, P., Guttorm, H., Kankkunen, T., Kokko, S., Kuoppamäki, A., Lepistö, J., Turkki, K., Väyrynen, L. & Lehtonen, J. (2011). Tytöille tyttömäistä ja pojille poikamaista – Yksilöllisten valintojen viidakossa? Sukupuolitietoisuus taito- ja taideaineiden opetuksessa ja tutkimuksessa. [Girly for the girls and boyish for the boys – in the jungle of individual choices? Gender awareness in teaching and research of art and skill subjects]. In J. Lehtonen (Ed.), *Sukupuolinäkökulmia tutkimusperustaiseen opettajankoulutukseen* (pp. 91–116). Helsinki: University of Helsinki.

Elshof, L. (2005). Teachers' interpretations of sustainable development. *International Journal of Technology and Design Education, 15*(2), 173–186. doi:10.1007/s10798-005-0916-z

Gendered Innovations (2013). *Gendered Innovations: How gender analysis contributes to research.* Research and innovation. Report of the expert group 'Innovation through gender'. European Commission.

Hilmola, A. (2015). Re-analysis of the assessment data of Finnish National Board of Education 2010. Available from the author.

Jakku-Sihvonen, R. (2013). *Sukupuolenmukaista vaihtelua koululaisten oppimistuloksissa ja asenteissa*. [Gender-based variation in pupils' learning outcomes and attitudes]. Koulutuksen seurantaraportit 2013:5. Finnish National Board of Education.

Järvinen, E.–M. & Rasinen, A. (2015). Implementing technology education in Finnish general education schools: studying the cross-curricular theme 'Human being and technology'. *International Journal of Technology and Design Education*, *25*(1), 67–84. doi:10.1007/s10798-014-9270-3

Keirl, S. (2011). Primary design and technology education and ethical technological literacy. In C. Benson & J. Lunt (Eds.), *International handbook of primary technology education: Reviewing the past twenty years* (pp. 235–246). London: Sense Publishers.

Klapwijk, R., & Rommes, E. (2009). Career orientation of secondary school students (m/f) in the Netherlands. *International Journal of Technology and Design Education, 19*(4), 403–418. doi:10.1007/s10798-009-9095-7

Kokko, S. & Dillon, P. (2011). Crafts and craft education as expressions of cultural heritage: individual experiences and collective values among an international group of women university students. *International Journal of Technology and Design Education, 21*(4), 487–503. doi:10.1007/s10798-010-9128-2

Lonka, K. (2015 October 7th). Panel discussion. Women in Tech forum, Helsinki.

Mammes, I. (2004). Promoting girls' interest in technology through technology education: A research study. *International Journal of Technology and Design Education 14*(2), 89–100.

National Core Curriculum for Basic Education 2004 (NCCBE 2004). Helsinki: The Finnish national board of education.

National Core Curriculum for Basic Education 2014 (NCCBE 2014). Määräykset ja ohjeet 2014:96. Tampere: Juvenes Print – Suomen Yliopistopaino Oy.

Niiranen, S. & Niiranen, S. (2015). Women in technology-oriented fields. Australasian Journal of Technology Education, 2.

Rasinen, A., Ikonen, P. & Rissanen, T. (2006). Are girls equal in technology education? In M. J. de Vries & I. Mottier (Eds.), International handbook of technology education: Reviewing the past twenty years (pp. 449–461). Rotterdam: Sense Publishers.

Rasinen, A., Ikonen, P., & Rissanen, I. (2011). Technology education in Finnish comprehensive schools. In C. Benson & J. Lunt (Eds.), *International handbook of primary technology education: Reviewing the past twenty years* (pp. 97–105). London: Sense Publishers.

Schreier, M. (2012). *Qualitative content analysis in practice*. London: Sage.

She Figures (2012). *Gender in research and innovation. Statistics and indicators.* European Commission.

Volk, K. S. (2007). Attitudes. In M. de Vries, R. Custer, J. Dakers & G. Martin (Eds.), *Analyzing best practices in technology education* (pp. 191–202). Rotterdam: Sense Publishers.

Wilkinson, T. & Bencze, L. (2011). With head, hand and hearth: children address ethical issues of design in technology education. In K. Stables, C. Benson & M. de Vries (Eds.), *Perspectives on learning in design & technology education* (pp. 406–412). Proceedings of PATT25/CRIPT8 conference. London: Goldsmiths, University of London.

A Pilot Study of the Technological Literacy among Primary School Teachers in Sweden

Tor Nilsson
School of education, culture and communication,
Mälardalen University, Sweden
tor.nilsson@mdh.se

Pernilla Sundqvist
School of education, culture and communication,
Mälardalen University, Sweden
pernilla.sundqvist@mdh.se

Peter Gustafsson
School of education, culture and communication,
Mälardalen University, Sweden
peter.gustafsson@mdh.se

ABSTRACT

A pilot study focused on technological literacy and the nature of technology was undertaken among 30 Swedish primary school teachers. This research utilised a study-specific questionnaire based on previous findings and was comprised of 62 items answered by the teachers using a Likert-type scale. The answers were analysed statistically to determine internal consistency and for further development of the questionnaire. In addition, a group of 6 teachers gave their views on why some of the items deviated. The results indicate that, in total, at least 7 of the 14 categories need further development, especially the 5 newly designed categories covering the critical aspects of technological literacy for which no descriptive categories were found in previous research. Factor analyses were also performed to explore data and look for indications of how these teachers' views of technology can be described. One 3-factor solution covered 2 dimensions (how technology is conceived and interaction with artefacts) as well as one 4-factor solution covering both of these dimensions and background variables. Although the sample size limits our conclusions, it is evident that some background variables explain more of the variation than would be possible if the sample had been larger. Even so, the analyses provide valuable input for the development of our ongoing research project.

INTRODUCTION AND BACKGROUND

Technology is an independent subject in Swedish compulsory schools. However, this does not automatically mean that primary school teachers have adequate training or even a developed and literate view of technology and the nature of technology (NoT). In the Swedish context, it has been found that technology as a school subject lacks an established teaching tradition (Björkholm, 2015) and is often overshadowed by other subjects (Skolinspektionen, 2014). This phenomenon has also been observed in other countries, such as England and The Netherlands (Benson, 2012; Koski, 2014). The teaching of technology traditionally emphasises activities, a "doing" and a design process of artefacts, while learning objects and objectives receive little attention from the teachers (Bjurulf, 2008; Jones, Buntting, & de Vries, 2013; Jones & Moreland, 2004). This

is a situation that appears to be especially common among primary school teachers (Björkholm, 2015; Blomdahl, 2007; Jones & Moreland, 2004; Rennie, 2001) illustrated in their difficulty with constructing and selecting content for teaching in relation to the subject syllabi.

Therefore, there is a clear need to develop a knowledge base for teaching technology in relation to technological literacy including insights into the NoT. There are several clear descriptions of technological literacy and NoT (American Association for the Advancement of Science, 1989; Collier-Reed, 2006; DiGironimo, 2010; International Technology Education Association, 2007; Mitcham, 1994) that are comprised of overlapping and complementary elements. They describe technology as a desire and ability to design and produce artefacts or systems for solving problems in relation to our human senses (and limitations within them), needs for transport of ourselves or objects, the artefact or system in and of itself and the control and use of the artefact or system as well as its impact on society and thereby its development from a historical perspective. The aim of this pilot study is therefore to map out the views of technological literacy and NoT among Swedish primary school teachers from preschool class up to Grade 6.

METHODOLOGY

A study-specific questionnaire covering teachers' background variables and three domains, how technology is conceived, one's interactions with technology and the ability to think critically about technology was developed from Collier-Reed's (2006) Technological Profile Inventory (TPI), Aikenhead, Ryan and Fleming's (1989) Views on Science—Technology Society (VOSTS) and Gamire and Pearson's (2006) Tech Tally: Approaches to Assessing Technological Literacy. All 41 items in Collier-Reed's questionnaire, including 'How technology is conceived' (five categories of descriptions, referred to as 'Txx' below) and 'Experiences of interacting with technological artefacts' (four categories of descriptions, referred to as 'Ixx' below), were translated and adapted to the Swedish primary school context. We chose to use a 6-point LT version of Collier-Reed's questionnaire for the following reasons: We focused on the width of how teachers conceive and interact with technology, not the TPI of each teacher, which the Collier-Reed's discrete option type gives since the teachers provide answers indicating the most preferred statement among 4 or 5 options. Also, when combining the TPI with Aikenhead et al. (1989) and Gamire and Pearson (2006), similar categories of descriptions did not exist for the critical dimension and therefore the DO-version was excluded. From VOSTS, items 40141 and 80211 resulted in 3 reformulated items with adaption to the Likert scale and 18 items were developed from Gamire and Pearson (2006). In total, 62 items were included in the questionnaire.

To test the questionnaire, a pilot study with primary school teachers was designed. Three schools with school classes including students of age 6 - 12 years old (preschool to Grade 6) in three different cities were invited. After an initial contact with the principal at each school we were allowed to ask all teachers by email to voluntarily and anonymously, in accordance with the ethical principles of the Swedish Research Council (Vetenskapsrådet, 2011), to fill out the questionnaire. The digital questionnaire was accessed through a link on the internet. Of 60 teachers 30 completed the questionnaire (3 males and 27 females). Among the respondents, 11 mainly worked in preschool classes, 14 in Grades 1 to 3 and 5 in Grades 4 to 6. Half of the teachers stated that they had received no education in technology during their teacher training, 6 of them had 6 weeks or more of full-time education in technology.

According to Collier-Reed (2006), both versions of the questionnaire need validation. Even though the power of our statistical analyses was low, as a first step we decided to explore the data (i.e., internal consistency and factor analysis) using IBM SPSS version 22 (alpha = 0.05). Hence, we did not validate the questionnaire in a true sense; instead, we investigated its translation and adaption to the Swedish context before performing a validation. Items identified as in need of revision was excluded based on the value of Cronbach's alpha (see corrected means in Table 1).

Next, the analysis provided input to a group discussion with 6 teachers. Having completed the questionnaire was not a prerequisite for participation in the group discussion. The teachers discussed both items and categories where the statistical analysis showed inconsistencies and gave their view on why some items deviated with respect to the other items and the meaning of each category. Recording was not permitted; instead, notes were taken. Below, the teachers' main thoughts on why some items deviated are summarized.

MAIN RESULTS

As only 30 teachers completed the questionnaire any statistical analysis must be viewed with great caution. Still, it has provided valuable input to the ongoing research project. With that in mind, the analysis of Collier-Reed's (2006) LT version shows that technology seems to be everything (Table 1). However, the corrected mean for the first category (TAA: Technology is conceived of as an artefact) was much lower, relatively speaking, than for the other categories (not statistically significant). Since technology often is conceived of as artefacts, this may be worth investigating further. Furthermore, the corrected mean for the interaction category I (ITD: Interaction with a technological artefact is through direction) was much lower, relatively speaking, than for the other categories in this dimension (not statistically significant). The correlation matrix revealed that neither TAA nor ITD correlated significantly with any other categories. Table 1 presents descriptive statistics indicating that some items and categories need further development, especially those based on Aikenhead et al. (1989) and Gamire and Pearson (2006) to connect technology to critical aspects in relation to, for example, ethics, integrity and safety.

Table 1. Cronbach's Alpha Values for Each Category

Outcome space	Category/ Abbreviation	Cron-bach's alpha	Mean (max)	Median	SD	Range (low-high)
Technology is conceived of as:	An artefact, TAA	(0,614) 0,639*	14,03* (24)	13,50*	4,71*	19* (5-24)
	The application of artefacts, TEA	(0,610) 0,635*	15,70* (24)	15,50*	4,39*	16* (8-24)
	The process of artefact progression, TAP	0,688	24,67 (30)	24,00	3,87	14 (16-30)
	Using knowledge and skills to develop artefacts, TKS	0,758	21,93 (30)	21,00	4,73	18 (12-30)
	The solution to a problem, TSP	0,688	24,00 (30)	24,00	3,98	14 (16-30)
Interaction with a technological artefact is through:	Direction, ITD	(0,604) 0,722*	8,67* (18)	8,00*	3,35*	13* (3-16)
	Instruction, ITI	0,512	18,57 (24)	19,00	2,86	12 (12-24)
	Tinkering, ITT	0,784	13,30 (24)	13,50	4,83	16 (6-22)
	Engaging, ITE	0,471	18,73 (24)	18,50	2,81	9 (15-24)
Critical part:	Surveillance	0,258	-	-	-	-
	Consumer power	0,144	-	-	-	-
	Safety	0,437	-	-	-	-
	Sustainability	0,160	-	-	-	-
	Ethics	-0,22	-	-	-	-

Note: Categories Txx and Ixx refer to Collier-Reed (2006); the others refer to areas developed within this pilot study. (N = 30).

* = Corrected value based on the exclusion of one item in the category,

\- = Not calculated due to the values of Cronbach's alpha.

Two different factor analyses were conducted to further explore the data. In the first analysis, all Txx and Ixx categories described in Table 1 were included; the second analysis also included background variables for the teachers. In the first analysis, 3 components were extracted; in the second analysis, there were 4 components. They are described qualitatively as follows:

1) The 3-Component Solution
   a. "Technology is conceived of as everything but the artefacts themselves, and how they are interacted with includes everything but being directed."
   b. "Technology is comprised of artefacts, and you should not engage with them."
   c. "Tell me what to do (direct me) in order to develop technology."
2) The 4-Component Solution

a. "I as a man with a lot of teaching experience; I conceive technology as everything but artefacts. I have had limited in-service teacher training in technology (and science), and I like to interact with the artefacts in multiple ways, but I don't like being told what to do with the artefacts."
b. "I as a woman with a limited amount of teaching experience; I conceive technology as everything but artefacts. I have had in-service teacher training in technology (and science), and I only interact with technology through instruction or engagement."
c. "Technology (and science) was part of my teacher education, and I have not received informal in-service teacher education in technology (or science). Still, technology is definitely not artefacts or the use of knowledge and skills, it is about tinkering with the artefacts and not being directed."
d. "As a young science teacher with informal in-service teacher training in technology (and science), I conceive technology as artefacts and interact with the artefacts by tinkering with them, but not through engagement."

The follow-up discussions with a group of teachers regarding how they interpret the items we excluded from TAA, TEA and ITD showed the following:

- In TAA, 4 of 5 items refer to artefacts or technological systems that are in use, whereas the fifth item — "A washing machine thrown on a rubbish dump with no motor or wire is no longer technology. It is just a thing." (Collier-Reed, 2006, p. 187) — concerns used technology. Hence, it is no longer used for the purpose it was built for. For these teachers, it is still a technological system, but with respect to the other items, it deviates.

- In TEA, we reformulated one item which then deviated; A computer is technology when you watch a movie using your wireless connection (the original item was, A television is technology when you can watch a movie on it using a signal from the air [Collier-Reed, 2006, p. 187]). According to the teachers, a computer is always technology and not only when you watch a movie, which causes this item to deviate from the other items.

- In ITD, 3 of the 4 items concerned passive engagement or a lack of confidence with technological artefacts (i.e., I prefer watching someone else, I let someone else do it, I seem to always do it wrong), whereas the fourth item concerns asking for permission "I always ask permission before I use some new technological thing in case I break it" (Collier-Reed, 2006, p. 187). The teachers stated that perhaps this question could not be adapted properly from a pupil perspective to a teacher perspective since asking for permission is an action and teachers are grown-ups so, do grown-ups really ask for permission?

DISCUSSION

In this pilot study Cronbach's alpha has been used to investigate the internal consistency of the categories investigated. Even if large parts of the questionnaire can be regarded as well-established and tested (Collier-Reed, 2006), since it stems from phenomenographic categories and outcome spaces, it has been transferred and adapted to a Swedish context with teachers as informants and, furthermore, expanded with critical aspect items. Also, within a phenomenographic research tradition, the categories are defined based on the researcher's interpretation of, in this case, contextualized statements within interviews. Hence, statements that the researcher regards as belonging to one category might be regarded as something else when interpreted by the teachers in this context without explaining the definitions present.

Regarding the internal consistency, a value for Cronbach's alpha around 0.60 is acceptable for a study of this size (Robinson, Shaver, & Wrightsman, 1991). Nearly all of our items from the Collier-Reed part of the questionnaire pass this criteria. However, for the outcome space, "Interaction with a technological artefact," the instruction (ITI) and engaging (ITE) categories fell below the criteria. Care must thus be taken when interpreting the results connected to these items. Also, the critical aspect items fell way below this acceptance criteria and could not be regarded as giving trustworthy results.

In relation to the factor analyses, a general question is raised of whether our sample of 30 teachers was too small for such an analysis (Zaho, 2009). In his overview, Zaho presents two possible directions, one with a minimum sample size and one related to the subjects-to-variables (STV) ratio (note in our text component equals Zaho's variable). As an established opinion, a sample size should, as a rule, be above or well above 100. But this is, at the same time, not backed up with substantial statistical research (Zaho, 2009). The standpoint seems to be based on opinions such as "there would seem little reason to doubt the reliability of factors derived from samples of 100 subjects'' (Kline, 1979, p. 40). However, in an empirical test by Arrindell and Van der Ende (1985, p. 167), "N = 50 was shown to be the minimum to yield a clear, recognizable factor pattern". The cut-off limit regarding sample size can thus be disputed.

When studying the STV ratio, matrix algebraic arguments claim that the sample size has to be twice the number of the variables (Kline, 1979). A survey by Osborne and Costello (2005) of 2 years' worth of PsychINFO articles using factor analysis showed that nearly two-thirds of the factor analyses had a STV of up to 10 to 1. Surprisingly, 1 of 6 of all analyses had an STV ratio of 2 to 1 or below, which is a matrix algebraic uncertainty. Our STV ratio of 10 to 1 or 7.5 to 1 is well within established and accepted limits.

Contrary to most previous standpoints (e.g., Mitcham, 1994) and a dimension in DiGironimo's (2010) framework, TAA had the lowest mean (in percentage of max), which was a surprise. All other categories were valued about the same (in percentage of max), but no significant differences were found. However, with respect to the chosen version of the questionnaire (LT), it seems evident that teachers should agree to general statements about technology. Still, the range and minimum to maximum values indicate that with a larger sample, the result may have been different. Also, Engström and Häger (2015) reported that only 40 of 223 teachers viewed Technology as artefacts and their functions. Even though we have not presented data for each teacher here, such an analysis is possible (Collier-Reed, 2006). Also, in the 3-component factor solution, TAA was absent in the first component (all other Txx's were present), whereas the second component only included TAA of all the Txx's. In the 4-component solution, the last component was comprised of TAA. Hence, the factor analyses show that artefacts do become important when describing how technology is conceived. However, our sample included 3 male teachers, 2 of which worked in Grade 4 to 6; they also happened to be the oldest teachers in the sample. Hence, our sample may therefore explain some of the variation in data (the first 2 components in the 4-component solution). Therefore, firm conclusions with respect to these components are limited. Also, the values of Cronbach's alpha varied within the outcome space: "Interaction with artefacts is through…" and the analysis shows that it was only possible to exclude one item (within ITD) to increase the values. What becomes evident (but not significant) from the data is that most teachers do not want anyone to direct them as they interact with artefacts. Still, 1 component in the 3-component solution indicates otherwise.

Easily concluded from Table 1 is that further improvement of the recently constructed critical part of the questionnaire is needed. Even though the items were selected from previous research (Aikenhead et al., 1989; Gamire & Pearson, 2006), the combination of items was unsuccessful. Still, the results give insight into possible improvements. For instance, we need to differentiate between surveillance in schools (e.g. including GPS to track pupils on field-trips) and surveillance in general (e.g. public places). A division is also needed between interest groups in the development of technology (consumer, manufacturer and politicians) and, furthermore, what actually counts as sustainable technology and what choices teachers are willing to make. Finally, in the ethics category, items triggered negative correlations when positive correlations were expected. In order to further explore this, subsets may be needed. However, as a drawback, this will add items to an already long questionnaire.

REFERENCES

Aikenhead, G. S., Ryan, A. G., & Fleming, R. W. (1989). Views on science-technology-society. *University of Saskatchewan. Report no. CDN. mc, 5*.

American Association for the Advancement of Science. (1989). *Science for all Americans: Summary, project 2061*: ERIC Clearinghouse.

Arrindell, W. A., & Van der Ende, J. (1985). An empirical test of the utility of the observations-to-variables ratio in factor and components analysis. *Applied Psychological Measurement, 9*(2), 165-178.

Benson, C. (2012). The development of quality design and technology in English primary schools: Issues and solutions. *PATT26: Technology education in the 21st century*, 81-88.

Bjurulf, V. (2008). *Teknikämnets gestaltningar: En studie av lärares arbete med skolämnet teknik [Construing technology as school subject : A study of teaching approaches]*. (Ph.D.), Karlstad University, Karlstad.   (Karlstad University Studies 2008:29)

Björkholm, E. (2015). *Konstruktioner som fungerar: En studie av teknikkunnande i de tidiga skolåren [Constructions in function – a study of technical knowing in primary technology education]*. (Ph.D.), Stockholm University, Stockholm.

Blomdahl, E. (2007). *Teknik i skolan: en studie av teknikundervisning för yngre skolbarn [Technology in the classroom – a study of technology education for younger children in compulsory school]*. (Ph.D.), Stockholm University, Stockholm.

Collier-Reed, B. I. (2006). *Pupils' Experiences of Technology: Exploring dimensions of technological literacy.* (Ph.D.), University of Cape Town, Cape Town.

DiGironimo, N. (2010). *What is technology? A study of fifth and eighth grade student ideas about the Nature of Technology.* (D.Ed.), University of Delaware.   (AAT 3423317)

Engström, S., & Häger, J. (2015). *Four teacher profiles within technology teaching*. Paper presented at the 29th PATT conference (Pupils Attitudes Towards Technology). Plurality and complementarity of approaches in design & technology education, Marseille, France.

Gamire, E., & Pearson, G. (2006). *Tech tally: Approaches to assessing technological literacy*: Island Press.

International Technology Education Association. (2007). *Standards for Technological Literacy: Content for yhe Study of Technology* (Third ed.): International Technology Education Association.

Jones, A., Buntting, C., & de Vries, M. J. (2013). The developing field of technology education: A review to look forward. *International Journal of Technology and Design Education, 23*(2), 191-212.

Jones, A., & Moreland, J. (2004). Enhancing practicing primary school teachers' pedagogical content knowledge in technology. *International Journal of Technology and Design Education, 14*(2), 121-140.

Kline, P. (1979). *Psychometrics and psychology*. London: Academic Press.

Koski, M. (2014). *Connecting Knowledge Domains: An Approach to Concept Learning in Primary Science and Technology Education.* TU Delft, Delft University of Technology.

Mitcham, C. (1994). *Thinking through technology: The path between engineering and philosophy*: University of Chicago Press.

Osborne, J. W., & Costello, A. B. (2005). Best practice in exploratory factor analysis: four recommendations for getting the most from your analysis. Pract Assess Res Eval 10. *Practical Assessment Research & Evaluation, 10*(7), 1-9.

Rennie, L. J. (2001). Teacher collaboration in curriculum change: The implementation of technology education in the primary school. *Research in Science Education, 31*(1), 49-69.

Robinson, J. P., Shaver, P. R., & Wrightsman, L. S. (1991). Criteria for scale selection and evaluation. *Measures of personality and social psychological attitudes, 1*(3), 1-16.

Skolinspektionen. (2014). *Teknik – gör det osynliga synligt. Om kvaliteten i grundskolans teknikundervisning [Technology - make the invisible visible. About the quality of primary school technology education]* (2014:04). Retrieved from http://www.skolinspektionen.se/sv/Beslut-och-rapporter/Publikationer/Granskningsrapport/Kvalitetsgranskning/Teknik--gor-det--osynliga-synligt/

Vetenskapsrådet. (2011). God forskningssed. Retrieved from Stockholm: https://publikationer.vr.se/produkt/god-forskningssed/

Zaho, N. (2009). The Minimum Sample Size in Factor Analysis Retrieved from https://www.encorewiki.org/display/~nzhao/The+Minimum+Sample+Size+in+Factor+Analysis

The Procedural Domain: Evidencing Task Performance in D&T Education

Adrian O'Connor
University of Limerick
Ireland.
adrian.oconnor@ul.ie

Niall Seery
University of Limerick
Ireland
niall.seery@ul.ie

Donal Canty
University of Limerick
Ireland
donal.canty@ul.ie

Abstract

As more and more schools look to integrate systems of online and blended learning into their classrooms, Design and Technology (D&T) continues to be recognised as a pedagogically rich environment to investigate the use of both collaborative settings (Drain, 2010; Hennessy & Murphy, 1999; Hong, Yu, & Chen, 2011; Rowell, 2002) and virtual learning technologies (Karakaya & Şenyapılı, 2008; McCormick, 2004). In spite of this, theoretical frameworks and practical models which help schools and teachers make effective decisions about online activities and blended resources that evidence task performance are sorely needed in D&T.

Design-based activity is intended to bring about required or desirable change in some aspect of the world, or in the learner, or both (Roberts, 2013). That is in ability, in knowledge, or in understanding. Given that procedural capability is at the heart of this matter (Kimbell, 1997) frameworks and models in D&T must demonstrate procedural knowledge exercised by the learners in the performance of design-based tasks. Accordingly, this paper explores the processes that evidence procedural development within online and blended environments.

In conjunction with a formative design-based activity the research participants (n=24) utilised an online platform supported on stationary and mobile technologies to authentically evidence the process and the product of their learning. Case study research as an evaluation method (Yin, 2013) was employed to document the complexity of design-based activity and fully attend to the contextual conditions of online and blended learning in second level education.

The observational monitoring of pupils online activity revealed 12 processes of procedural development as being functionally activated and evidenced by pupils in the performance of design-based activities. Although the processes themselves are not unique, the contribution of this research is the synergy connecting these processes which can operationalise the delivery of an educational transaction and support meaningful

interactions within the learning environment. By providing diagnostic and formative evidence with regards to pupils' level of understanding and the degree of knowledge required and attained, these processes inform the nature of the pedagogical approach and can begin to influence the development of theoretical frameworks and practical models to enhance task performance in D&T education.

Keywords: Problem Based Learning; Learning Environments; Interaction; Pedagogy

Background

Creativity and innovation are leading topics for the 21st century both at the policy and the institutional level. Design and Technology (D&T) education has a special importance in promoting creativity and innovation, particularly when conceptual and procedural aspects of the design process reciprocally support one another (McCormick, 1997). Although, it has become common practice for pupils of D&T to take part in creative and innovative activities either in pairs or small groups, the complex and multidisciplinary nature of design-based activity calls for intensive collaboration across a variety of domains (Seitamaa-Hakkarainen, Kangas, Raunio, & Hakkarainen, 2012). Collaboration here is defined as a process in which pupils actively work together in creating and sharing their design ideas, deliberately making joint decisions and producing shared design objects, constructing and modifying their design solutions, as well as evaluating their outcomes through discourse (Hennessy & Murphy, 1999). Though difficult to provide evidence of, this approach necessitates a dialectic practice that values the pupils' own voice as authentication of both collaborative problem solving and interdependency in performance assessment while maintaining a focus on the overall design solution. Subsequently, in an effort to document the complex and fundamentally non-linear nature of design-based activity the use of collaborative settings (Drain, 2010; Hennessy & Murphy, 1999; Hong et al., 2011; Rowell, 2002) and the role of virtual learning technology in the area of D&T education has increased (Karakaya & Şenyapılı, 2008; McCormick, 2004). However, as more and more schools are looking towards the use of collaborative settings and virtual learning technology, theoretical frameworks and pedagogical models which help us to understand the nature of tasks performed when using systems of online learning and enhance the quality of learning and efficacy of teaching in D&T education are sorely needed.

Emerging Technology Platforms

In recent years, Information and Communications Technology (ICT) has integrated itself into a wide range of social, cultural and educational aspects of young people's lives to the point where it has become a ubiquitous element of pupils' experiences outside the classroom (Kimbell, 2008). In general, traditional practice allows for education and instruction to be delivered in a physical classroom setting and the current practices of online and blended learning allows for education and instruction to be delivered primarily via the internet in a virtual classroom setting, or in part via the internet in a virtual classroom setting with some element of a physical classroom setting. However, as more schools are continuing to install wireless broadband systems and pupils' access to mobile technology becomes increasingly ubiquitous (Williams & Kimbell, 2012), the historical impediments to the delivery of online learning are rapidly disappearing and the lines between physical and virtual settings are becoming increasingly blurred. Therefore, with the latest advancements in ICT, education and instruction are no longer confined to a 'classroom' setting as new configurations for the delivery of education and instruction

are now possible in almost any conceivable setting. This development not only changes our modes of communicating and accessing information but creates new spaces for learning and ways of interacting that challenge the limitations of the well-founded understanding of classical interaction: one user–one computer–one setting.

Klokmose (2006) defines this new form of interaction as ubiquitous interaction (UI) and this new kind of learning as ubiquitous learning (UL) or uLearning. UI presents schools with the capacity to extend learning beyond the physical classroom setting which allows pupils to "construct their learning through their environment and at their individual learning rates" (Brown, 2004, p. 36). This enables the development of a ubiquitous learning environment (ULE) whose borders are only limited by the imagination of those who participate within them (i.e. teachers, pupils) blurring the traditional institutional, spatial and temporal boundaries of schooling (Cope & Kalantzis, 2008). ULE`s establish a hybrid setting which allows education and instruction to be delivered traditionally and/or via the internet by seamlessly embedding virtual presence into the physical classroom setting. Accordingly, UL has been defined as an educational paradigm which takes place in the context of ubiquitous computing that provides the right support, in the right time and place, at the right level (Yahya, Ahmad, & Jalil, 2010).

Enhancing Traditional Practice
O`Connor, Seery, and Canty (2015) reported on an exploratory case study that looked at the effects of integrating UI on traditional practice in D&T education in two ways: 1) during the learning process (e.g., the effects on learning development and/or growth during the task); 2) the pupils' products (e.g., the effects on pupils' performance at the conclusion of the task). In conjunction with a formative design activity delivered during participant's regular scheduled class time, their approach integrated an online learning platform supported on stationary computers and mobile technologies (e.g. smartphones, tablets, etc.). This allowed pupils to:

- **Construct** theoretical knowledge and practical skills as shared practice.
- **Capture** the learning process and evidence of their learning in real time.
- **Communicate** a/synchronously with other participating group members.
- **Cogitate** their learning process in collaborative and individual contexts.

Though contextually set within D&T, these elements of learning pupils engaged in are more about doing, thinking, feeling and watching, i.e. features of experiential learning (Kolb, 1984). The suggestion is that UI facilitated a process of 'learning from experience'. Accordingly, O`Connor et al. (2015) proposed the *Experiential Domain* (see Figure 1). It is posited that this domain which has an adaptive educational transaction at its core can begin to describe and map learning as an evidence-based progress through each stage within the domain (i.e. construct, capture, communicate, and cogitate). Cognisant of the direction of new knowledge which is linked to existing knowledge, where deeper understandings are developed from, and take the place of, previous understandings. The aim of this pedagogical approach is to move the learners understanding along a path of increasingly complex knowledge and skills by focusing on their readiness to learn and subsequently building upon their current stages of understanding. As this process develops through the learners practical activity and social interaction with others (teachers, peers), O`Connor et al. (2015) posit that by integrating the Experiential Domain we can begin to trace the complex and fundamentally non-linear nature of design-based learning, documenting both the individual and collaborative evidence of the learners thinking and reflection processes displayed throughout the educational transaction.
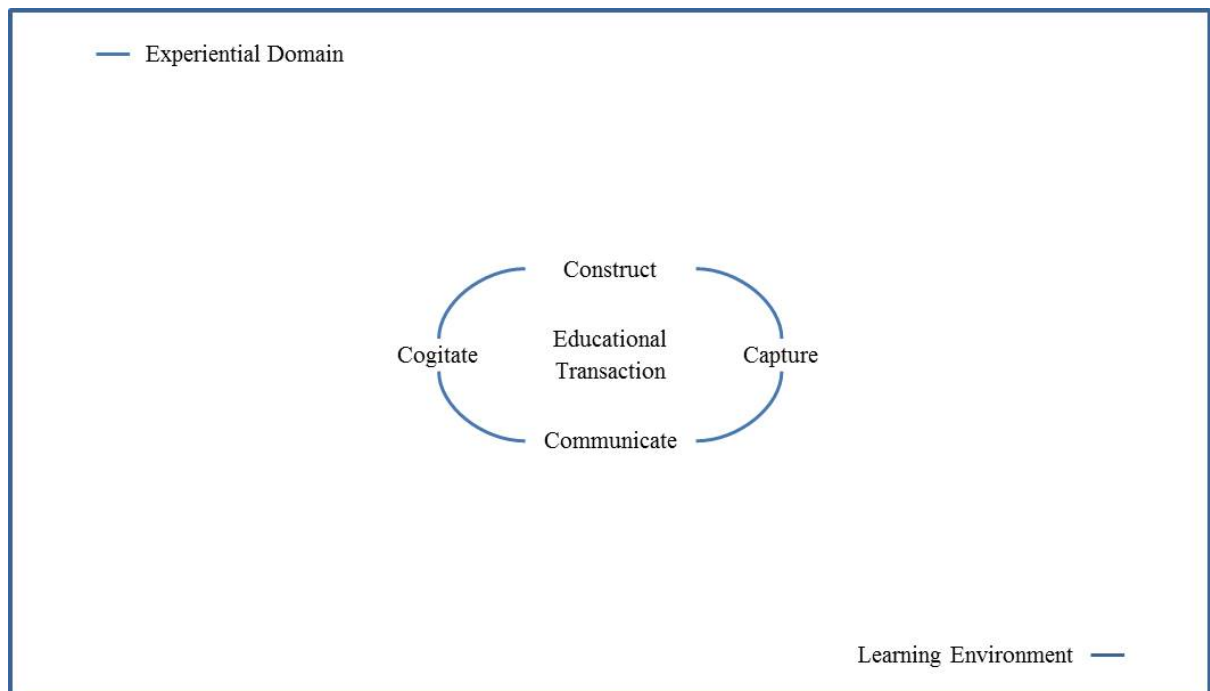
Figure 18 The Experiential Domain

Evidencing Task Performance

Although the Experiential Domain can be used in the planning and implementing of suitable tasks, it does little to inform the learning outcomes and associated technological knowledge of D&T education. For teachers to be able to plan and implement a unit of work that is based on authentic technological practice they must have a good understanding of the conceptual, procedural, societal and technical knowledge relevant to the practice (Fox-Turnbull, 2006). While effective teaching and assessment in D&T is positively influenced by the development of all four knowledge domains (Moreland, Jones, & Chambers, 2001), procedural knowledge is a major component in successful learning within D&T (McCormick, 1997; Turnbull, 2002). In contrast to declarative knowledge, procedural knowledge is goal oriented and mediates problem-solving behaviours. Hence, the general consensus is that procedural knowledge is the "know how" or ability to carry out action sequences (i.e. procedures) in solving problems. .

D&T is unique in involving procedural problem-solving activities where talk between teachers and pupils relates to physical manipulation and feedback, and both concrete models and graphical representations play an important mediating role in learning (Hennessy & Murphy, 1999). However, despite the importance of procedural knowledge in supporting this dialectic activity, earlier studies (Moreland & Jones, 2000) suggest that teachers are unable to define the procedural learning outcomes of the tasks they devised for the classroom experience. This made it almost impossible for teachers to provide formative feedback and interaction to enhance the quality of pupils' task performance. Instead, there were a lot of praise-based interactions, mostly related to task completion, not the strengths or weaknesses of the work related to the criteria or objectives of the tasks. This resulted in teachers having difficulties making statements about pupil learning that would be useful for future teaching and learning. Therefore, the purpose of this research was to investigate the individual processes that evidence procedural knowledge and understanding when problem-solving in D&T education.

Method
Given that UI and the on-going experiences of this interaction is the actual subject of study, the automatically recorded and machine-readable timeline of interactions generated by this technology offers a compelling source of data. Nonetheless, to document the complexity of a ULE and attend fully to its contextual conditions, case study research as an evaluation method (Yin, 2013) was required. As in O`Connor et al. (2015), this single-case study was contextually set within D&T and was carried out over a two week period. The study was conducted during the participants regular scheduled class time and consisted of two single 40 minute periods and one double 80 minute period per week. The participants of the study involved 24 pupils (8 Female, 16 Male) ranging in age from 13 - 14 and their class teacher.

Approach
Central to the delivery of the approach was the design of the educational transaction. This took the shape of a formative learning activity which required pupils to create an artefact to be personal to the user and relative to the environment in which it would be placed. Secondly, in an effort to map the stages of learning involved in the educational transaction the approach was grounded in the Experiential Domain. This allowed pupils to construct, capture, communicate, and cogitate evidence of their learning process and the product of their learning. Finally, to establish a ULE the approach integrated a commercially viable learning management system (LMS) which was supported on both stationary computers and mobile technologies (e.g. pupils smartphones, tablets, etc.). This approach facilitated a means to code the dynamics of UI using qualitative data analysis software. Evidence-based tags were then generated which led to using key words to describe the actual data collected. After each piece of data was initially tagged, all data was imported into qualitative data analysis software and coded more precisely at the individual word level. Once all codes were established, the analysis procedures for case studies as described by Stake (1995) were followed as the research sought to model the processes of procedural knowledge that emerged from the data, and to place our findings within O`Connor et al. (2015) framework.

Data Collection
Given that UI inherently offers a kind of participant-observation this was the predominant method of data collection encompassed by this research. Observation as a research process is a highly flexible form of data collection that presents opportunities to gather "live" data from naturally occurring experiences (Cohen, Manion, & Morrison, 2011) and permits access to interactions in a "lived" context and keeps systematic records of these to compliment other kinds of data (Simpson & Tuson, 2003). Therefore, the use of observation as a principle mode of analysis has the potential to yield more valid or authentic data than would otherwise be the case with mediated or inferential methods. Observational data is sensitive to context under examination and demonstrates strong environmental validity (Moyles, 2002) enabling the research to gather information on: physical settings (environment); human settings (behaviour); interactional settings (discourse); and programme settings (content). Gold (1958) offers a well-known classification of researcher roles in observation that lie on a continuum from complete participation to complete detachment. This research employed the role of the observer-as-participant which is found within the mid-point of this continuum. The observer-as-participant is not a member of the group, but may participate a little or peripherally in the group's activities, and whose role as a researcher is clear and overt, as unobtrusive as possible. This afforded the opportunity to not only observe the educational transaction

as a researcher but also participate actively in the case being studied, taking part in UI. All interactions were archived throughout the educational transaction for data analysis purposes. This enabled the following categories of information to be analysed in order to investigate the dynamics of UI in modelling the processes of procedural knowledge: settings; participants; experiences; goals; acts; events; time; meanings; relationships; and feelings.

Findings

The behaviours observed as pupils attempted to construct evidence of both their learning process and the product of their learning, first saw pupils try and conceptualise theoretical knowledge and practical skill as a process of creating a mental grasp of "something", to develop an initial idea or feeling. Working iteratively by uploading data files (evidence) and posting annotative comments to the LMS, pupils then tried to externalise the key features of the initial construction, giving abstract meaning to some or all elements of the idea or feeling. Subsequent emotional or intellectual activity resulted in the pupils trying to formalise some kind of visual, aural, verbal, and/or physical outcome. Thus, pupils were seen to be applying tangible substance to practise or test the newly constructed idea or feeling. Using key words to describe the actual data collected, evidence-based tags labelled the behaviours observed as the following processes of procedural development: conceptualise, externalise, formalise.

As pupils attempted to capture evidence of their learning (i.e. process and product), the following processes that evidence procedural development within a ubiquitous environment were identified. Firstly, the data collected saw pupils try to analyse the meaningful qualities of an active construct by examining an idea or feeling in order to explain and interpret it. Secondly, pupils tried to synthesise their perceived knowledge and skill to form a logical connection between their evidence and their experiences, making what was known about an idea or feeling into a coherent whole. Finally, the behaviours observed as pupils attempted to capture their learning showed pupils trying to rationalise their understanding. Hence, pupils were seen to be qualifying the importance or significance of a particular idea or feeling, even if the actual idea or feeling was later rejected by the pupil for being inapt. Once each piece of data was initially tagged, the processes of procedural development were coded more precisely at the following individual word levels: analyse, synthesise, rationalise.

The first process to be observed as pupils attempted to communicate the evidence of their learning saw pupils try and form general accounts, principles or conclusions by inferring from observable phenomenon which resulted in pupils then trying to generalise and bring their understanding of specific experiences into common knowledge. Hence, pupils were tagged as describing broad statements or applications of an idea or feeling. This resulted in pupils trying to hypothesise a possible explanation or direction for an idea or feeling. Lastly, pupils sought to theorise a unifying explanation for a set of verified, proven factors, associated with the data presented to communicate evidence of their learning. Accordingly, pupils were seen to be reasoning supporting principles to substantiate an idea or feeling. Evidence-based tags labelled the aforementioned processes of procedural development using the following key words to describe the actual data uploaded by the pupils: generalise, hypothesise, theorise.

The behaviours observed further indicated that UI had the effect of continually requiring pupils to cogitate evidence of both their learning process and the product of their learning. By virtue of meaningful interactions in the ULE, pupils were seen to revise an

idea or feeling, by looking back over it in part, or in full, to correct or better it. This created the conditions to reorganise or change the way in which an idea or feeling had been formulated in the light of additional evidence. Lastly, pupils were seen to recognise their course of intentionality, knowing how to progress or reconstruct an idea or feeling. The process of using evidence-based tags and key words to describe the data collected was finalised with the recognition of the following three processes of psychological development: revise, reorganise, recognise.

As shown in Table 1, this research has classified 12 developmental processes that evidence learners' procedural knowledge and understanding when problem-solving in D&T education. These 12 processes not only provide diagnostic and formative evidence about pupils levels of understanding or their degrees of knowledge required and attained but offers a compelling source of data that can lead to discussions about the quality of learning and the efficacy of teaching. The classification of the Procedural Domain can also begin to help us articulate a common language of progression and to enhance task performance within D&T education.

Table 11 Processes of Procedural Development

Process	Description
Conceptualise	Creating a mental grasp of something to develop an idea or feeling.
Externalise	Giving abstract meaning to some or all elements of an idea or feeling.
Formalise	Applying tangible substance to practise or test an idea or feeling.
Analyse	Examining an idea or feeling in order to explain and interpret it.
Synthesise	Making what is known about an idea or feeling into a coherent whole.
Rationalise	Qualifying the importance or significance of a particular idea or feeling.
Generalise	Describing broad applications or conclusions from an idea or feeling.
Hypothesise	Suggesting a possible explanation or direction for an idea or feeling.
Theorise	Reasoning supporting principles to substantiate an idea or feeling.
Revise	Looking over an idea or feeling in part or in full to correct or better it.
Reorganise	Changing the way in which an idea or feeling has been formulated.
Recognise	Knowing how to progress or reconstruct an idea or feeling.

Discussion

O`Connor et al. (2015) sought to investigate the effects of integrating UI on traditional classroom practice. As a result of that investigation their study found that UI advocates a process of learning from experience and subsequently classified the Experiential Domain - a pedagogical approach to teaching and learning which demonstrates evidence-based progress through each stage of an educational transaction in a ubiquitous environment. Although, what was being investigated by this study is different from the previous work, the procedures for the delivery of an educational transaction set within the Experiential Domain as described by O`Connor et al. (2015) were followed as this research sought to investigate the dynamics of UI in modelling the processes of procedural development. As presented in Figure 2, once the processes that evidence procedural development had been identified, this research was able to place its findings in O`Connor et al. (2015) framework of existing research and theory. Correspondingly, this research puts forward the 'Procedural Domain'. This domain posits a pedagogical approach to teaching and learning which activates the processes that evidence procedural development while operating in the Experiential Domain.
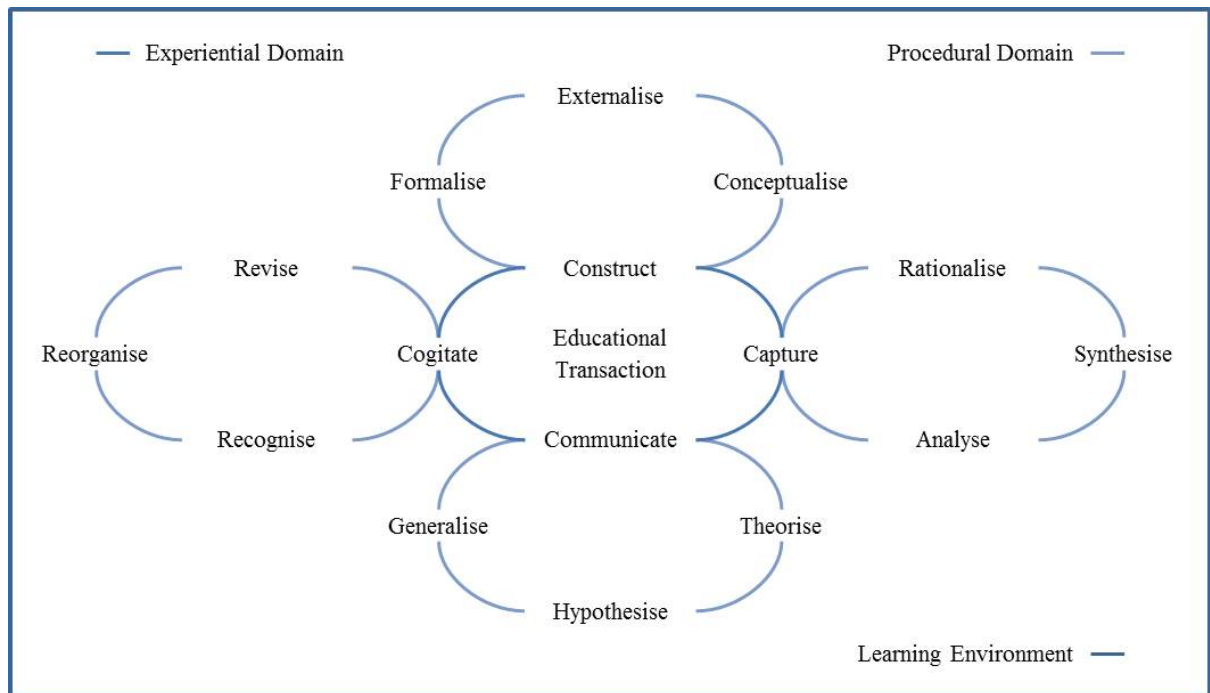
Figure 19 The Procedural Domain

Conclusion

In discussing the findings of this study, it is important to keep a couple of things in mind. This evaluation case is still a preliminary step in a relatively new field of investigation, one that includes practicum experiences with a single cohort and new ubiquitous configurations for teaching and learning designed to enhance task performance in D&T education. Also, we are not privy to whether or not this study documented the complexity of the learning environment absolutely or attended fully to its contextual conditions. Certainly, due to the adaptive nature of the educational transaction and the idiosyncratic disposition of the participants within the learning environment, a lot more could have been happening. Any summary that could be made in this space would be too brief to be of use and would have been beyond the limitations of this evaluation case. In other words, this study is not a definitive report but an introductory analysis based on the observation of 24 pupils, 1 teacher and their responses to the integration of a new pedagogical approach within D&T education.

In conclusion, the Procedural Domain can be used to support discourse, inform the design, facilitation and direction of procedural knowledge for the purpose of realising personally meaningful and educationally worthwhile learning outcomes to influence the development of theoretical frameworks and practical models to enhance task performance in D&T education.

References

Brown, K. (2004). Technology: building interaction. *TechTrends, 48*(5), 34-36.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7 ed.). Milton Park, Abingdon, Oxon, [England]: Routledge.

Cope, B., & Kalantzis, M. (2008). Ubiquitous learning: An agenda for educational transformation. In B. Cope & M. Kalantzis (Eds.), *Ubiquitous learning*. Champaign, IL: University of Illinois Press.

Drain, M. (2010). Justification of the dual-phase project-based pedagogical approach in a primary school technology unit. *Design and Technology Education: an International Journal, 15*(1).

Fox-Turnbull, W. (2006). The influences of teacher knowledge and authentic formative assessment on student learning in technology education. *International journal of technology and design education, 16*(1), 53-77.

Gold, R. L. (1958). Roles in sociological field observations. *Social forces, 36*, 217-223.

Hennessy, S., & Murphy, P. (1999). The potential for collaborative problem solving in design and technology. *International journal of technology and design education, 9*(1), 1-36.

Hong, J.-C., Yu, K.-C., & Chen, M.-Y. (2011). Collaborative learning in technological project design. *International journal of technology and design education, 21*(3), 335-347.

Karakaya, A. F., & Şenyapılı, B. (2008). Rehearsal of professional practice: Impacts of web-based collaborative learning on the future encounter of different disciplines. *International journal of technology and design education, 18*(1), 101-117.

Kimbell, R. (1997). *Assessing technology: International trends in curriculum and assessment: UK, Germany, USA, Taiwan, Australia*: McGraw-Hill Education (UK).

Kimbell, R. (2008). Innovative performance and virtual portfolios-a tale of two projects. *Design and Technology Education: an International Journal, 11*(1).

Klokmose, C. N. (2006). *An instrumental paradigm for ubiquitous interaction*. Paper presented at the 6th Danish Human-Computer Interaction Research Symposium, Aarhus, Denmark.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.

McCormick, R. (1997). Conceptual and procedural knowledge. *International journal of technology and design education, 7*(1-2), 141-159.

McCormick, R. (2004). Collaboration: The challenge of ICT. *International journal of technology and design education, 14*(2), 159-176.

Moreland, J., & Jones, A. (2000). Emerging assessment practices in an emergent curriculum: Implications for technology. *International journal of technology and design education, 10*(3), 283-305.

Moreland, J., Jones, A., & Chambers, M. (2001). Enhancing student learning in technology through enhancing teacher formative interactions. *Research Information for Teachers, 3*.

Moyles, J. (2002). Observation as a research tool. In M. Coleman & A. Briggs (Eds.), *Research methods in educational leadership and management* (pp. 172-195). Thousand Oaks, CA: Sage Publications.

O`Connor, A., Seery, N., & Canty, D. (2015). *The experiential domain: Enhancing practice in design and technology education*. Paper presented at the 29th Pupils' Attitude Towards Technology Conference, Marseille, France.

Roberts, P. (2013). The aims of design education. In K. Baynes & E. Norman (Eds.), *Design education: A vision for the future* (pp. pp. 34-40). Leicestershire: Loughborough Design Press Ltd.

Rowell, P. M. (2002). Peer interactions in shared technological activity: A study of participation. *International journal of technology and design education, 12*(1), 1-22.

Seitamaa-Hakkarainen, P., Kangas, K., Raunio, A.-M., & Hakkarainen, K. (2012). Collaborative design practices in technology mediated learning. *Design and Technology Education: an International Journal, 17*(1).

Simpson, M., & Tuson, J. (2003). *Using observations in small-scale research: A beginner's guide*. Glasgow: The SCRE Centre.

Stake, R. E. (1995). *The art of case study research*. Thousand Oaks, CA: Sage Publications.

Turnbull, W. (2002). The place of authenticity in technology in the New Zealand curriculum. *International journal of technology and design education, 12*(1), 23-40.

Williams, J., & Kimbell, R. (2012). Conclusion. *International journal of technology and design education, 22*(2), pp. 265-270.

Yahya, S., Ahmad, E. A., & Jalil, K. A. (2010). The definition and characteristics of ubiquitous learning: A discussion. *International Journal of Education and Development using Information and Communication Technology, 6*(1), 1.

Yin, R. K. (2013). *Case study research: Design and methods* (5 ed.). Newberry Park, CA: Sage Publications.

21st century skills: how to identify and address them in technology education

Margarita Pavlova
Hong Kong Institute of Education,
Department of International Education and Lifelong Learning
mpavlova@ied.edu.hk

This paper presents a conceptualization of the 21st century skills developed by the International Study of City Youth (ISCY) project in which HKIEd is a participant. The ISCY examines education systems around the world by focusing on a number of cities worldwide and surveying fifteen-year-old students in those contexts. One of the intentions of ISCY was to measure 21st century skills (often referred to as non-cognitive skills, such as perseverance, creativity, empathy, confidence and hope for the future) that are critical for students' transition to life beyond school. A theoretical framework that conceptualizes 21st century skills was developed by Lamb (2015) and was based on work by Pellegrino & Hilton (2012) and Farrington et al (2012). The framework focuses on four *academic mindsets* supported by *effort* and *engagement*, certain *social skills* and *learning strategies.*

The paper argues that the development of 21st century skills can be well addressed through teaching and learning in technology education, as one focus of the subject/learning area is to ensure the successful transition to life beyond school and to support students' academic achievement. This paper provides some examples of research in technology education relevant to this area. In addition, it is suggested that by applying a survey methodology based on the ISCY framework it is possible to identify those skills that require improvements in particular settings, in order to devise targeted approaches that address the identified differences.

Keywords: 21st century skills; taxonomy of 21st century skills; measurement of 21st century skills; academic mindsets; International Study of City Youth (ISCY) study; technology education

Introduction

Many scholars have stressed the importance of 21st century skills. These skills are often called non-cognitive skills or capabilities and are required to meet the demands of "21st century work" (Silva 2008, p. 1). Alongside core literacy and numeracy they constitute a different dimension of learning that should occur in schools and other educational institutions and can be considered crucial for the transition to life beyond school. Analysis of government policies on the integration of these skills into education and training in the Asia and the Pacific region (UNESCO, 2015), for example, concludes that the rationale for including 21st century skills in education is based on a combination of socio-economic and value-based thinking. Although economic discourse currently prevails (governments in the region want to boost economic development), considerations of social, ethical and other attributes among students seems also important for some countries (e.g. the Republic of Korea, Malaysia and Thailand). The summary of the different rationales and types of 21st century skills are presented in Table 1.

Table 12: Rationale for the integration of transversal/21st century skills in education

	Economic Discourse	**Social Discourse**	**Humanity Discourse**
Global Perspective	Competitiveness	Understanding & Peace	Global Citizenship
National Perspective	GDP Growth	HDI Growth	Patriotism
Personal Perspective	Employability	Community/Harmony	Moral Formation

Source: Kim, C.H., Tam, A. and Trzmiel, B. (in press) based on ERI-Net study, UNESCO, 2015

Despite some governments' efforts to address the necessity for 21st century skills development, there are many challenges to resolve including reaching a consensus on the nature of these skills and the ways to measure them. Although current research on non-cognitive skills presents various taxonomies of 21st century skills (e.g., Farrington et al 2012; Gutman & Schoon 2013) there is still no agreement on precisely what these skills are or how to measure them.

This paper originated as a result of the International Study of City Youth (ISCY) led by Professor Lamb, Victoria University, Melbourne, which examines education systems around the world in the context of a city. The ISCY is an on-going longitudinal international study that explores how system-level factors translate into differing outcomes for 15-year-old students. The ISCY baseline data collection was conducted in 12 cities around the world in 2013–2014, with around 30,000 students taking part. The significant part of the study is an investigation into how well education systems foster a broad range of learning and life skills such as perseverance, creativity, empathy, confidence and hope for the future. The intention of this paper is to present a conceptualization of the 21st century skills developed in the ISCY study that enable them to be measured and also to argue that these skills can be successfully addressed in technology education classrooms.

Taxonomies of 21st century skills

Current research on non-cognitive skills includes recent attempts to synthesize international literature in identifying various taxonomies of 21st century skills (Farrington et al 2012; Gutman & Schoon 2013). Gutman & Schoon's analysis (2013) indicates that there is little agreement on the nature of these skills or how to measure them. Table 2 presents eight categories of skills found in the literature, the degree of agreement on their taxonomy, whether they are malleable as well as the strength of evidence with respect to their effect on other outcomes.

*Table 13: **Gutman & Schoon's summary of findings on non-cognitive (21st century) skills***

	Quality of measurement	**Malleability**	**Effect on other outcomes**	**Strength of evidence**
1. Self-perceptions Self-concept of ability	High	Medium	Not available	Medium
Self-efficacy	High	High	High	Medium
2. Motivation Achievement goal theory	High	Medium	Low to medium	Medium
Intrinsic motivation	High	Medium	Low to medium	High
Expectancy-value theory	Medium	Not available	Medium to high	Medium
3. Perseverance				

Engagement	Medium	Not available	Not available	Low
Grit	Medium	No evidence	No evidence	Low
4. **Self-control**	Medium	Low to medium	Low	Medium
5. **Meta-cognition**	Medium	Medium to high	Medium to high	High
6. **Social competencies**				
Leadership skills	Low	Not available	No evidence	Low
Social skills	Medium	Medium to high	Low to medium	High
7. **Resilience & coping**	Medium	High	Low	Medium
8. **Creativity**	Medium	Not available	No evidence	Low

Source: Gutman & Schoon 2013, p. 2.

Taking into account the existing research on 21st century skills combined with the lack of consensus on their typology, the ISCY study developed an approach to grouping 21st century skills, or competencies, under the three categories that schools strive to instil in their students:

- ***Creative learners***, *who think critically, make discoveries, use technology, solve problems, communicate their ideas to others and adapt to change with optimism and hope for the future.*
- ***Ethical citizens***, *who build relationships based on fairness, respect, empathy and compassion, and to contribute fully to the community and the world through teamwork and collaboration.*
- ***Motivated achievers***, *who create opportunities and achieve goals through hard work, perseverance and discipline, exercise leadership, and demonstrate confidence and resilience* (Lamb, 2013).

The ISCY student survey contains over 200 items that explore students' backgrounds, attitudes, opinions and values, so students' self-evaluation of 21st century skills constitutes just a part of it. A number of constructs were identified under the above three categories:

Creative learners

Constructs:

- Creativity measures students' ability and inclination to come up with new ideas.
- Problem-solving measures students' ability to devise solutions and overcome obstacles.
- Communication measures students' skills in oral and written communication.
- Expertise with computers measures whether students are "expert" with computers.
- Hope for the future measures students' optimism and happiness with their future.

Ethical citizens

Constructs:

- Teamwork measures students' ability to work in groups and get along with others.
- Perspective taking measures students' open-mindedness and empathy with others.
- Fair-mindedness measures whether students treat others fairly and value fairness.
- Altruism measures students' propensity to help others, including through voluntary work.
- Informed citizenship measures students' belief in the need to be aware of political issues.

Motivated achievers

Constructs:

- Conscientiousness measures the level of effort students apply to their schoolwork.
- Perseverance measures students' willingness to persist with difficult tasks.
- Personal management measures students' time management and organizational skills.
- Leadership measures whether students believe they are good at leading others.
- Life satisfaction measures students' happiness with life outside of school, and overall.

Several items were selected as possible measures for each construct. However, for the *initial analysis of results only one item was identified to measure each construct.* This item was recognized as a best measure by using factor analysis to identify the strongest weighting. Where two items had strong weightings, the item with the most responses was selected. For example, four items were identified initially as best describing the problem-solving skills construct:

a. I can think of many ways to reach my current goals* [Chinese version]
b. There is little that can prevent me from reaching my goals
c. There are lots of ways around any problem that I am facing now
d. I like to think of new ways to do things* [English version]

Subsequently item a) was selected for the Hong Kong (HK) group and item d) for all other cities, as they had the strongest weightings for different contexts.

Although scaled variables usually use multiple items, this single-item approach has been utilized to illustrate key constructs in the initial ISCY reports, as calibrated multiple-item scales cannot be developed until the international data collection is complete. It is also important to state that students rated *themselves* on the above three categories, and the results identified differences between different city settings. For example, the analysis of Hong Kong students' perspective revealed that they are lacking some skills related to motivation and creativity, however, they received a very high score as ethical citizens. However, when compared with their international peers, HK students are lacking on hope for the future and life satisfaction; leadership, personal management; and partially on problem solving.

The initial analysis of responses raised a number of issues, but one in particular: how to conceptualize 21st century skills in a way that would make it possible to rationalize the fostering of their development.

The ISCY model for conceptualizing 21st century skills

A theoretical framework was developed for the ISCY study by Lamb (2015) that conceptualizes 21st century skills based on Pellegrino & Hilton's (2012) and Farrington et al's (2012) taxonomies. The first approach bridges the gap between personality traits and 21st century skills and the second links 21st century skills with students' achievements and stresses the importance of developing *academic mindsets*. The framework proposed by The University of Chicago Consortium on School Research (CCSR) (Farrington et al,2012) focuses on four *academic mindsets* supported by *effort* and *engagement*, certain *social skills* and *learning strategies* (see Figure 1). This model helped to organize ISCY survey items into a series of scales that reflect current understandings of 21st century skills. It also demonstrates how they might operate in interconnected ways to improve student learning. Although ISCY cannot claim to comprehensively measure all the complex constructs in this model, it provides a means to organize ISCY survey items into a series of scales with which to measure important 21st century skills.

Figure 20 **CCSR'S hypothetical model of the relationship between non-cognitive factors (21st century skills) and academic performance**
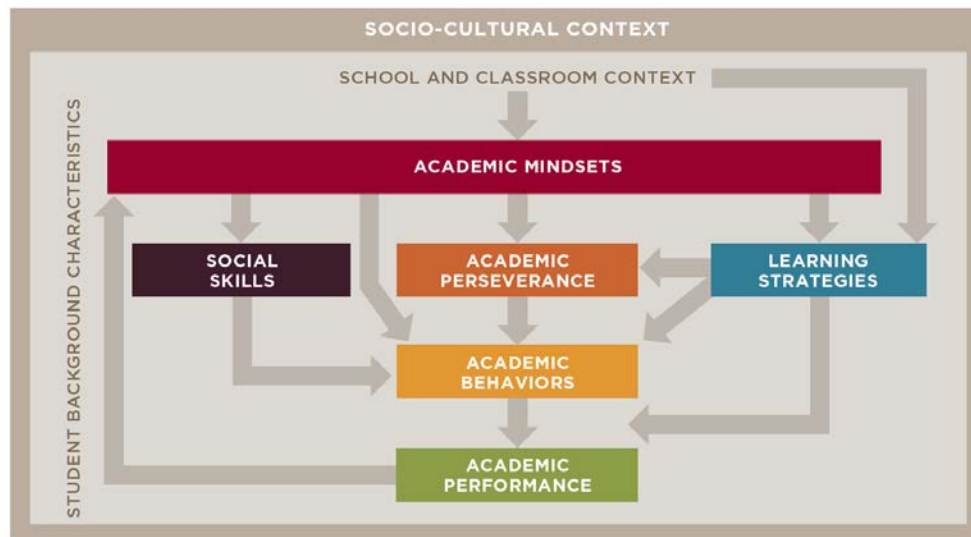
Source: Farrington et al 2012, p. 12.

After adopting the CCSR's hypothetical model, the ISCY student survey items relevant to each construct were identified. For example, the self-efficacy (I can succeed) construct can be measured by such items as i) Results I expect to get in my studies; ii) How my teachers rate me as a student; and iii) I am confident of doing well in school, etc. Following the identification of the items, the validity and reliability of these scales were established. For each item in all constructs a simple table of correlations was created using data from seven cities available at the time. Items that did not have a moderate correlation (>0.4) with any other item were excluded. After a number of additional manipulations nine principle components that reflect a logical conceptual grouping was established. The reliability of these nine scales was then tested, using Cronbach's Alpha, for each of the seven individual cities.

As a result, a hypothetical model was developed for the ISCY study (see Figure 2). Four academic mindsets, such as belonging, self-efficacy, hope and purpose are positioned as supporting a construct labelled *academic focus* that comprises of *effort* and *engagement*, which influences *academic performance*. These constructs are also supported by certain *social skills* and learning strategies measured in ISCY, which reflect the core 21st century skills identified in the literature. The ISCY framework also outlines the role of cognitive skills (also tested by the ISCY) in supporting academic performance (Lamb, 2015). Further analysis during the project on the relationship between the nine ISCY scales (Figure 2) will test these assumptions.

Although this framework does not explicitly relate mindsets/21st century skills to the effectiveness of transition to life after school, other research demonstrates their importance (see, for example, Shectman et al, 2013; Trilling & Fadel, 2009).

Mindsets development in technology education

The analysis of the articles published in the *International Journal of Technology and Design Education* over the last five years (all issues between 2011 and 2015) and the first issue of 2016 revealed that not much attention has been given to the development of students' mindsets through technology education. One paper on a particular aspect of mindsets, *hope*, by Douglas and Strobel (2014) presents the ways to measure elementary students' attitudes towards science, engineering and math, along with hope they may have related to school and the future. More papers focus on one particular aspect – creativity. Bruton (2011), for example, examines a pedagogical framework that fosters learning for innovation and creativity in higher education. Campbell and Jane (2012) discuss the deep

learning that stimulates creativity. Hargrove (2013) argues that the application of a metacognitive approach and available technologies can contribute towards the development of creative thinking abilities in students.

One paper that was published earlier than the analyzed period is also worth mentioning. Barak's paper (2010) focuses on another aspect of mindsets, namely *self-efficacy*. It discusses the model that highlights the interrelationships between the cognitive, metacognitive and motivational aspects of learning, problem-solving and invention.

This short review identified a gap in technology education research that relates to a systematic analysis of 21st century skills and the ways they can be addressed in technology education. The research by The University of Chicago Consortium on School Research (CCSR) suggests that rather than attempting to foster particular skills, educators should focus on cultivating mindsets as skills are "not directly malleable and depend considerably on context" (Nagaoka et al. 2013, p.48). The mindsets presented in Figure 2 can be developed through technology education and can be contextualized to different technology education settings. For example, a *purpose* (value what I do here) can include issues of sustainability as essential contexts for design and technological activities.

Conclusions

This paper examined the way 21st century skills are conceptualized and measured through the ICSY study, and presents a framework that links these skills to academic achievement as well as transitions from school to work. Conceptualizing them as mindsets can be helpful in contributing towards their development through technology education, as one focus of the subject/learning area is to ensure a successful transition to life beyond school. The analysis of some published research in technology education also reveals that systematic studies into the ways these mindsets can be developed and contextualized in technology education classrooms are required. In addition, by applying a survey methodology, based on the ISCY framework, it is possible to identify the particular skills that require further improvements in different settings so that targeted approaches can be developed.

Figure 2—ISCY framework for 21st century skills and academic mindsets, showing items used in each scale

ACADEMIC MINDSETS

BELONGING
(*I belong* here)

I like being at school
I feel happy about my life at school
I will leave this school with good memories
I feel safe at school

SELF-EFFICACY
(*I can* succeed)

Results I expect to get in my studies
How my teachers rate me as a student
I am confident of doing well in school
Right now I see myself as being pretty successful as a student

HOPE
(*I will* find a way)

There are many ways to reach my goals
Little can stop me from reaching my goals
There are lots of ways around any problem that I am facing now
I am confident of finding a good job when I finish my studies
I feel happy about my future

PURPOSE
(*I value* what I do here)

What we learn in class is necessary for success in the future
My classes give me useful preparation for what I plan to do in life
School teaches me valuable skills
Working hard in school matters for success in the workforce

SOCIAL SKILLS

COLLABORATION

I get along well with others
I understand how others are feeling
I work well in groups
I treat others fairly
I take time to help others

ACADEMIC FOCUS

ENGAGEMENT

I find most school work boring [R]
School is often a waste of time [R]
I get a feeling of satisfaction from what I do in class
Level of interest in school work

EFFORT

In class, I work as hard as possible
In class, I put in my best effort
In class, I keep working even if the material is difficult
I always try to do my best
I am a hard working student

LEARNING STRATEGIES

CREATIVITY

I am good at coming up with new ideas
I am good at getting ideas across in discussions
I like to think of new ways to do things
I am good at leading others
I express ideas clearly in oral /written presentations

SELF-MANAGEMENT

I often leave things to the last minute [R]
I tend to be lazy [R]
I am easily distracted in class [R]

ACADEMIC PERFORMANCE

References

Barak, M. (2010). Motivating self-regulated learning in technology education. *International Journal of Technology and Design Education, 20*(4), 381-401. doi: 10.1007/s10798-009-9092-x

Bruton, D. (2010). Learning creativity and design for innovation. *International Journal of Technology and Design Education, 21*(3), 321-333. doi: 10.1007/s10798-010-9122-8

Campbell, C., & Beverley, J. (2010). Motivating children to learn: the role of technology education. *International Journal of Technology and Design Education, 22*(1), 1-11. doi: 10.1007/s10798-010-9134-4

Douglas, K. A., & Strobel, J. (2014). Hopes and goals survey for use in STEM elementary education. *International Journal of Technology and Design Education, 25*(2), 245-259. doi 10.1007/s10798-014-9277-9

Farrington, C. A., Roderick, M., Allensworth, E., Nagaoka, J., Keyes, T.S., Johnson, D.W., & Beechum, N.O. (2012). *Teaching adolescents to become learners. The role of noncognitive factors in shaping school performance: A critical literature review.* Chicago: University of Chicago Consortium on Chicago School Research.

Gutman, L. M., & Schoon, I. (2013). *The impact of non-cognitive skills on outcomes for young people: Literature review*. London: Institute of Education.

Hargrove, R. A. (2013). Assessing the long-term impact of a metacognitive approach to creative skill development. *International Journal of Technology and Design Education, 23(*3), 489-517. doi: 10.1007/s10798-011-9200-6

Kim, C. H., Tam, A., & Trzmiel, B. (in press). Transversal skills: A missing link between school and work. In M. Pavlova, C-K. J. Lee & M. Rupert (Eds.), *Transitions to Post-School Life: Responsiveness to Individual, Social and Economic Needs*. Springer

Lamb, S. (2015). *Measuring 21st Century Skills in ISCY. A discussion paper.* Retrieved from https://iscy.org/wp-content/uploads/2015/12/ISCY-21st-Century-Skills-Framework.pdf

Lamb, S. (2013). *Framework for the first report. A discussion paper*. Unpublished, Victoria University, Australia: Centre for International Research on Education Systems.

Nagaoka, J. Farrington, C.A., Roderick, M., Allensworth, E., Keyes, T.S., Jonson, D.W. and Beechum, N. O. (2013). Readiness for College: the role of Noncognitive Factors and Context. *Voices in Urban Education*, *38*, 45- 52. Retreived from https://consortium.uchicago.edu/sites/default/files/publications/VUE%20Noncognitive%20Factors.pdf

Pellegrino, J. W., & Hilton, M. L. (Eds.). (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* National Research Council. Washington DC: The National Academies Press.

Shectman, N., DeBarger, A. H., Dornsife, C., Rosier, S., & Yarnall, L. (2013). *Promoting grit, tenacity, and perseverance: Critical factors for success in the 21st Century.* Draft report for the US Department of Education. Retrieved from: http://pgbovine.net/OET-Draft-Grit-Report-2-17-13.pdf

Silva, E. (2008). *Measuring skills for the 21st century.* Retrieved from http://educationpolicy.air.org/sites/default/files/publications/MeasuringSkills.pdf

Trilling, B., & Fadel, C. (2009). *21st century skills: Learning for life in our times.* San Francisco: Jossey-Bass.

UNESCO. (2015). *Integrating transversal competencies in education policy and practice (Phase I)*. Bangkok: UNESCO

The ethos of the discourse concerning the future and technology

Antti Pirhonen
Department of Teacher Education
University of Jyväskylä, Finland
antti.pirhonen@jyu.fi

Abstract

The so-called 21st century skills have become an established concept to refer to the challenges of formulating educational objectives in today's rapidly changing world. As such, in basic education in particular, it is difficult to find common ground for engaging in these types of discussions across different cultures. The first ambiguous, culture-specific concept is education, the content and domain of which vary significantly. The second related issue is technology in education, and the third is education's role in creating the future.

In order to avoid over-simplifications, we have chosen to analyse this topic by focusing on one country: Finland. In the study, we analysed the content of the Core Curriculum of Basic Education (2004, 2014) document in Finland (Finnish National Board of Education, 2014). We looked for references to the future and to technology. We then compared our findings with the overall ethos of the discourse.

Our central finding was that, in general, the Finnish educational system is very ambitious. Its objective is to educate active, independent, critical, self-regulated, creative constructors of the future, whose activities are based on the shared ethical values of society. When referring to technology and the future, however, the tone of the discourse changes; the objective appears to shift to creating a flexible conformist who takes the technological changes in the world as given.

We conclude that the conflict between the general ethos of the Core Curriculum and the components that are concerned with technology and the future add an interesting perspective to the discourse on the role of technology in society.

Keywords: Future, technology, curriculum

Introduction

School-related discussions in various contexts—whether among members of the public or within professional communities— tend to bind two concepts tightly together: technology and the future. This combination has been established over time. An obvious interpretation of this association is that we find the increase in the use of technology to be inevitable when we envision the future.

The so-called 21st century skills play a natural role in the conceptual framework of the future and technology. We first assume that the quality and quantity of technologization will continue to evolve just as it has in the recent past. The conclusion is that the world of tomorrow requires new kinds of skills to cope with and utilise the technology that is emerging. Thus, the challenge for educational systems is to provide students with those skills.

In our view of the dynamics of the development of societies, the concept of 21st century skills is deeply rooted in an approach that stresses the *necessities* instead of the *opportunities*. This view seems to encompass an assumption that the changes occurring in the world are mechanical consequences of the circumstances. The best we can do is to be prepared for the unavoidable. Typically, talking about the emerging opportunities is making virtue of necessity.

This article questions this stereotypical perspective. The idea that an educational system's primary role is to provide people with the means to survive in a future world is utterly pessimistic and

unambitious. Therefore, I conceptualise the concept of the future world as something to be constructed rather than as something that is a given.

As an illustration of the proposed approach and its implications, I reflect upon the Core Curriculum of Basic Education (2004, 2014) framework that is used in Finland (Finnish National Board of Education, 2014). (Since the 2014 version of this document is not yet available in English, all references to that document are unofficial translations provided by the author). However, I begin by describing the role and the nature of basic education in Finnish society. I then analyse the Core Curriculum, focusing on the occurrences of references to the future and technology. After that, I reflect upon the specific peculiarities of the Core Curriculum with the concept of 21st century skills. Finally, I conclude by proposing an alternative way to approach the role of technology in education.

Understanding the nature of the Finnish educational system

When discussing the Finnish educational system, it is impossible to avoid references to Finland's success in the Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA) studies. While Finland's success has been hailed all over the world, the announcement of the first PISA results created a domestic sensation. Namely, the Finnish comprehensive school system, a creature and cornerstone of the Finnish welfare society, was criticised from the start (early 1970s) for being too radical in equalising pupils, thus destroying opportunities for gifted students to fully develop their talents. It was only the announcement of PISA results that silenced the critics.

We have learned that talents are evenly distributed throughout all social classes. School achievements are more strongly linked to socioeconomic background than talent (e.g. Plank, 2001). As a small nation, Finland cannot afford to lose its intellectual resources by only offering the opportunity to obtain a high-quality education to a privileged set of citizens. The long tradition of valuing education is indicated by the high level of teacher education and the popularity of and appreciation for the teaching profession.

Since the renewed focus on teacher education in the late 1970s, all teachers in Finnish comprehensive schools are required to hold a master's degree in educational sciences. In addition to these high educational standards, teachers were allotted a fairly high degree of freedom to organise how they teach. Today, the document that teachers share and use is the Core Curriculum of Basic Education (2004, 2014). This document provides teachers with broad educational principles and objectives. However, the practical issues of organising school life are largely left to individual teachers. In other words, teachers are trusted to be highly educated experts who are supposed to be able to plan their own work.

The Core Curriculum of Basic Education

In light of the nature of the Finnish educational system, it is interesting to take a closer look at the Core Curriculum of Basic Education, especially from the perspective of the theme of this article: the future and technology.

In everyday conversations among teachers, it is safe to argue that the aim of education is to prepare pupils for the future. However, that objective is not found in the actual text of the Core Curriculum of Basic Education (2014). In reality, the ethos of the document is quite the opposite. That document divides the main level objectives of basic education into seven categories. One category is titled: "Participation, influencing and the constructing of sustainable future". This idea is embedded throughout the document, and it is found in the descriptions of all subjects in relation to teaching different grade levels. For instance, "The mission of basic education" (in sub-section 3.1) states: "In basic education the needs for changes are learned to be faced openly, assessed critically, and to take up the baton of the choices that construct the future.

For most of the statements concerning the future and society, it can be interpreted that the goal of a Finnish comprehensive school is to educate an active, highly civilised constructor of a better world. However, as seen in the previous version of the Core Curriculum document, the tone

changes when references are made to technology (Pirhonen, 2010). For example, the description of the main level objective #2, titled "Thinking and learning to learn", states: "Skills for learning to learn are accumulated when pupils are instructed, in the way that suits to their age, to set objectives, plan their work, evaluate their progress and *utilise* technological and other tools in their studies".

In objective #3, "Taking care of oneself and everyday skills", the word, technology, is salient, for instance:

Pupils need basic knowledge about technology, its development and its impact in different walks of life and environment. They also need advice in sensible technological choices. In teaching, the diversity of technology is handled, and the principles of its functions are guided to be understood, as well as the formation of costs. In basic education, pupils are guided to responsible use of technology and the ethical questions concerning it are discussed.

As seen in the quotes presented above, technology is utilised, chosen and discussed. In all other walks of life, the objective is to prepare people to be active, critical agents. When it comes to technology, the view of world is much more limited, if not pessimistic. Someone out there is designing technology that can be utilised by citizens who have been educated in comprehensive schools. The contrast between the overall objectives and objectives related to technology is so strong that the entire Core Curriculum document can be interpreted to be internally contradictory.

The importance of technology in the mind of the authors of Core Curriculum becomes evident when counting the occurrence of the term in the whole text. In the 463 page long document term technology is mentioned 263 times in 130 paragraphs. Of these, 55 paragraphs deal with the use of technology in everyday context, 75 paragraphs the use of technology in education. 18 occurrences deal with the use of technology as a means of expression. These were related to music, art and crafts. It appears that technology has been added to most any content area, at least by reminding that technology should be utilised in teaching. The form in which the educational technology emerges in different parts of the document is highly repetitive; apparently the same phrases have been copy-pasted to each subject.

Thus far, this analysis has focused on the occurrence of the term technology. The new, 2014 version of the Core Curriculum of Basic Education places a strong emphasis on certain kinds of technology, namely information and communication technology (ICT). In that document ICT is referred to much more frequently than technology in general. As a topic, ICT has been found to be so central that it has been included as one of the seven first level objectives, titled "ICT ability". That theme is further divided to four sub-themes, as follows:

1) Pupils are guided to understand the use and functional principles as well as focal concepts of information and communication technology, and to develop their practical ICT skills in the compilation of their own works.

2) Pupils are guided to use information and communication technology in a responsible, safe and ergonomic manner.

3) Pupils are taught to use information and communication technology in data management as well as in explorative and creative work.

4) Pupils get experiences and practise the use of ICT in interaction and networking (Core Curriculum of Basic Education, 2014).

At first sight, all these sub-themes appear to be politically correct. However, after closer inspection it becomes clear that even under the specific ICT-title, technology, itself, is a given. The sub-themes encourage students to *use* and *practise the use of* ICT.

In reading between the lines of the Core Curriculum document, it is easy to see that the authors find ICT — and probably technology in general — to be a tool that enables users to perform actions so they can be active agents in the construction of the world. That might have been a valid claim a few decades ago, but the world has changed since that. The era when information technology was primarily used by a small number of people and mostly in an industrial context, is very different from the world in which we now live. ICT appears mostly in the widespread use of consumer

products. Indeed, the marketing mission of ICT products and services has been extremely successful in terms of the number of ICT devices and the amount of usage time. However, as Papert (1980) noted decades ago, the problem lies in how digital tools, which have been designed in terms of a certain context and a specific scenario, would work when they are used for a completely different kind of purpose. Most of the current ICT products and services have been designed for use by massive numbers of consumers, rather than by learners. The primary criteria used to design ICT for use in a commercial context may be very different from, if not opposite to, the criteria used to design ICT for use in an educational context. For instance, consumer products appeal to the minimisation of effort: everything must be easy, fast and fun. In contrast, learning is often difficult, slow and dull. Therefore, we should be critical when introducing consumer products as educational tools.

21st century skills in light of Core Curriculum

As Rotherham and Willingham (2010) pertinently stated, there not much is novel in the fashionable notion of the so-called 21st century skills (see e.g. P21, 2010). Most of the skills that are typically listed under this title have been essential for a long time in all the sophisticated educational systems of modern societies.

Most basic education teachers around the world probably agree on the ideas associated with 21st century skills. However, when searching for information about this on the web, two themes related to 21st century skills frequently appear. The first theme is the skills related to technology. This is already a cliché; every day we hear how the societies of tomorrow require new kinds of technical skills—and, typically, this refers to digital technology. In other words, the underlying assumption is that people need more skills to use and cope with the ever-increasing amount of digital products around us. The interesting question then is: What are these mysterious skills? The forms of digital products and services change so fast that if pupils learn to use them today, their skills are likely to be useless once they have grown up, have graduated from school and are integrated into society. In the past, only one skill—the touch-type system—was relevant for decades, and it could be used over several generations of digital technology However, with the introduction of touch-screen based tablets, even effective typing has lost its relevance in many contexts.

So, what should be taught at schools in order to provide students with the appropriate skills they need in order to use future types of technology? When MS Windows' use of logic was changed in the mid-1990s, users of the old version had more difficulties adapting to the new version than people who first started to use a personal computer with the new operating system. On the other hand, ease-of-use has become a key criterion in the development of user-interface technology. User interfaces are getting easier and more intuitive all the time. In other words, people need fewer and less specific 'skills' to use digital technology. The conclusion is that, at least in some respects, the need for computing skills is overstated.

From the point-of-view of Core Curriculum, the concept of the technologization of our societies looks very different. Since the aim of the Finnish comprehensive school system is to educate highly civilized constructors of the world, all kinds of premises about the nature of future society become irrelevant. Thus, the skills and abilities that help create novel ideas and implement them in a cooperative manner, are valuable regardless of how the world may look tomorrow. As educators, we should support the young generation and, above all, trust that they'll make wise choices in the unknown future.

The second theme that is salient in the literature of 21st century skills is assessments. The topicality of assessments can be seen as a reflection of the conceptions of education. The Finnish language does not have a good counterpart for the English word *education*. For instance, the Finnish counterpart of 'educational science' could be translated as 'the science of upbringing'. Thus, Finnish education goes beyond schooling; it is fundamentally about the interactions among human beings. Therefore, the most important objectives of the Core Curriculum cover the development of the whole person. Since these aims are so extensive and are articulated to span a

person's entire lifetime, it is not possible to measure the success of the most important objectives. In other words, Finnish schooling is based on trust in highly educated teachers, and, within a classroom, trust in pupils.

Discussion and Conclusion

Quite recently, dark clouds have hovered over the Finnish schools: we learned that our ranking in the latest PISA studies dropped (OECD, 2014). This can be partly explained by the success of some Asian countries—thus, the drop is relative. However, some of this decline is absolute. The interesting thing here is that the decline coincides with the massive introduction of digital technology in Finnish schools, as well as the increasing control of schools and individual teachers by school administration. From the point-of-view of the Core Curriculum, even if the PISA ranking is definitely not an essential measure of success, it is interesting that the trust based, democratic Finnish school has also managed to produce high achievement in traditional academic skills. Now, when the original virtues of the Finnish education system are questioned, for instance by forcing teachers to adopt methods and approaches that they don't claim as their own, the international ranking of Finnish schools has dropped.

The conclusion that can be drawn from this is that if we aim at educating capable constructors of the future world, digital technology (or any other predefined technology) is not the key to success, nor is focusing on a fixed vision of the future. The only sustainable basis for a school system that contributes to wellbeing, creativity and happiness is to create an environment that fosters democracy, trust and values, and teaches good practical and academic skills.

References

Finnish National Board of Education (2004). National Core Curriculum for Basic Education 2004. Vammala: Vammalan Kirjapaino.

Finnish National Board of Education (2014). Perusopetuksen opetussuunnitelman perusteet 2014. (English version: National Core Curriculum for Basic Education, in press). http://www.oph.fi/download/163777_perusopetuksen_opetussuunnitelman_perusteet_2014.pdf (accessed 18.5.2016).

Papert, S. (1980). Mindstorms: Children, computers, and powerful ideas. New York (NY): Basic Books.

Pirhonen, A. 2010. Do we bring up passive conformists or active constructors? Some thoughts about technological determinism and its reflections in Finnish comprehensive school. In Rasinen, A. & Rissanen, T. (eds.) In the spirit of Uno Cygnaeus – Pedagogical questions of today and tomorrow. 200th anniversary of the birthday of Uno Cygnaeus Symposium October 12-13, Jyväskylä, Finland. Jyväskylä: Department of Teacher Education, University of Jyväskylä, 143-150.

OECD (2012) PISA 2012 Results in Focus: What 15-year-olds know and what they can do with what they know. https://www.oecd.org/pisa/keyfindings/pisa-2012-results-overview.pdf (accessed 13/5/2016)

Plank, S. B., & Jordan, W. J. (2001). Effects of information, guidance, and actions on postsecondary destinations: A study of talent loss. American educational research Journal, 38(4), 947-979.

P21. (2016) http://www.p21.org/about-us/p21-framework (accessed 11/5/2016)

Rotherham, A. J., & Willingham, D. T. (2010). "21st-Century" Skills. American Educator, 17.

Investigating the Factor Structure of Pupils Attitudes towards Technology

Jason Power
University of Limerick
jason.power@ul.ie

Jeffrey Buckley
University of Limerick
jeffrey.buckley@ul.ie

Niall Seery
University of Limerick
niall.seery@ul.ie

Donal Canty
University of Limerick
donal.canty@ul.ie

Abstract

As STEM education becomes the focus of educational reforms in knowledge based economies, technological literacy is seen as a key outcome of many STEM related programmes. When considering technological literacy it is vital that educators are cognisant of the attitudinal dimension. This is especially true when developing a programme of Initial Technology Teacher Education (ITTE) as efforts aimed at developing technological literacy of future teachers have the potential to achieve exponential impacts throughout the career of technology educators.

Students of technology teacher education are in a period of attitudinal malleability due to the paradigm shift from being a pupil to an educator. Coupled with their attitudinal disposition being of paramount importance within their oncoming professions, there is a pedagogical need to monitor their perceptions of technology education throughout their degree programme. This paper presents the initial phase in an envisioned longitudinal study to design a comprehensive tool with the capacity to elicit such perceptions across the broad spectrum of factors which constitute to technology education, with the focus of this particular phase being on attitudes towards technology.

The Pupil's Attitudes Toward Technology (PATT) tool was adapted for use in an ITTE degree programme. The instrument was administered to a cohort (N=124) of student teachers in the first and last week of their first semester within the programme. Within this semester, students complete modules relating to educational theory, design, graphical communication, and manufacturing technology.

The results of this study identify a five factor model as the model of best fit. Further interpretation of the factors within this model suggests similar factors to those which emerged from previous studies. This study has generated significant insight into ITTE students' attitudes towards technology, however due to its pilot nature further work is needed to draw definitive results.

Introduction

In recent years there has been a considerable emphasis placed upon the inclusion of increased levels technology within the classroom as a proposed solution to what many feel are pedagogical deficiencies (Buabeng-Andoh, 2012). This agenda is born from the societal need for increased technological proficiency to facilitate students ineluctable introduction to operating in a conceptual age (Pink, 2005). Therefore, the ongoing drive for higher levels of technology within classrooms is considered axiom. Instead, the focus of this paper will be on associated attitudes towards technology.

Albarracin, Zanna, Johnson and Kumkala (2005) posit that attitudes are malleable. From a pedagogical position this is of significant interest as research has shown that students who demonstrate a positive attitudinal disposition towards a particular area of study also demonstrate higher interest levels and performance within that area (Krathwohl, Bloom, & Bertram, 1964). This suggests that student teachers who demonstrate a positive attitudinal disposition towards technology will be more likely to achieve the required levels of technological literacy (Bame, Dugger Jr, de Vries, & McBee, 1993).

This is especially important in the context of future technology teachers. Technology educators are conceptualised as the epicentre of a ripple effect where an effective educator has the potential to influence the technological literacy of thousands of students across their career. Considering the magnitude of effect that teachers can have on pupils (Hattie, 2008), pertinent attitudes of teachers are therefore of paramount importance. The amalgam of the criticality of technological literacy, in conjunction with the potential impact of teachers, merits the adoption of an attitudinal lens when examining pedagogical practices within Initial Technology Teacher Education (ITTE).

Attitudes towards Technology in Initial Technology Teacher Education

Investigations into attitudes towards technology were instigated by de Vries (1988) through the development of the Pupils Attitudes Toward Technology (PATT) tool. This tool contains multiple items designed to gain insight into pupils' attitudes relative to a variety of aspects associated with technology such as gender and societal roles, education and employment perspectives, and general interest. This has subsequently been re-developed for use within the USA (Bame et al., 1993) suggesting the efficacy of the original tool as a valid methodological foundation requiring surface level re-contextualisation for different environments.

Students within an ITTE programme are constantly subjected to information pertinent to technological advances and regularly engage with active and experiential learning methodologies where relevant technology is ubiquitous. Learning outcomes are regularly associated with developing technological competencies such as technological capability and technological literacy. As such attitudes towards technology should refine and develop continuously throughout their degree programme. This is in turn based on the supposition that the learning outcomes related to enhanced technological literacy and technological understanding are achieved.

Research Focus

Due to the nature of the environment embodied within ITTE where pedagogical practices both drive and respond to technological evolutions, this creates the need for a tool with the capacity to validly and reliably elicit attitudes towards technology in this dynamic context. It is posited that such a tool would require regular adaptations over time in response to the constantly changing setting. Therefore, the first phase in the development of such a tool is to elicit the broad factors associated with attitudes towards technology in this context. The development of this tool would then facilitate the investigation of the pertinent attitudes of students during their engagement with ITTE modules.

Method

The purpose of this research agenda is to elicit the factor structure of the PATT tool as a foundation for the development of a new tool capable of validly and reliably interpreting student teachers attitudes towards technology education. Specifically, this study sought to gain insight into the factor structure of ITTE students' attitudes towards technology to support further investigation into additional constructs meriting inclusion the aforementioned tool.

Research has previously been conducted with the intent of eliciting the factor structure of the PATT tool (Ardies, de Maeyer, & Gijbels, 2009; Bame & Dugger Jr, 1989). This research guided the methodological design of this study however due to the different context minor changes were made to the approach. It was decided that the original version of the PATT tool (de Vries, 1988) would be adapted to align with this new context based on the large number and non-domain specific nature of the items. In order to update the scale, and adapt to the domain of operation, various adaptations were made to the original PATT tool. A ten-point Likert scale was also utilised due to the anticipated small sample size as the additional variance has been found to be more reliable with smaller cohorts (Wittink & Bayer, 1994). The use of a ten-point scale has also been shown to be comparable with five and seven point scale for analytical tools such as confirmatory factor analysis (CFA) which is a core aspect of the method employed in this study (Dawes, 2008). However, it is intended to revert to the original five point scale subsequent to this pilot phase.

A test/re-test approach using the adapted 89 item scale was utilised. New entrants into an ITTE programme completed the pre-test before engaging in any technology related module. After the conclusion of their first semester participants again completed the same 89 item version of the scale. Upon completion of the study samples were considered valid if a complete pre and post data set was available. This resulted in 113 valid data sets. A series of statistical analyses were subsequently conducted to determine the underlying factor structure of the tool.

Statistical Analysis

A series of both exploratory factor analyses (EFA) and confirmatory factor analyses (CFA) were conducted to elicit the underlying factor structure of the PATT tool. Cohen, Manion and Morrison (2007) identify a need for 150 respondents and a minimum of 5 theoretical items loading on each factor for the purposes of this analysis. The number of respondents in this study (n=113) did not meet this criteria however as this was an exploratory study designed with the intent of gaining insight to inform the progression of the envisioned longitudinal study this was deemed acceptable.

Initially an EFA was run on the results from the pre and post-tests with oblique promax rotation and no limitation on the number of factors to retain. The scree plots for both suggest an underlying 5 factor model and are illustrated in Figure 1. The eigenvalues, explained variance and cumulative explained variance of these five factors for the pre and post-test samples are illustrated in Tables 1 and 2 respectively.
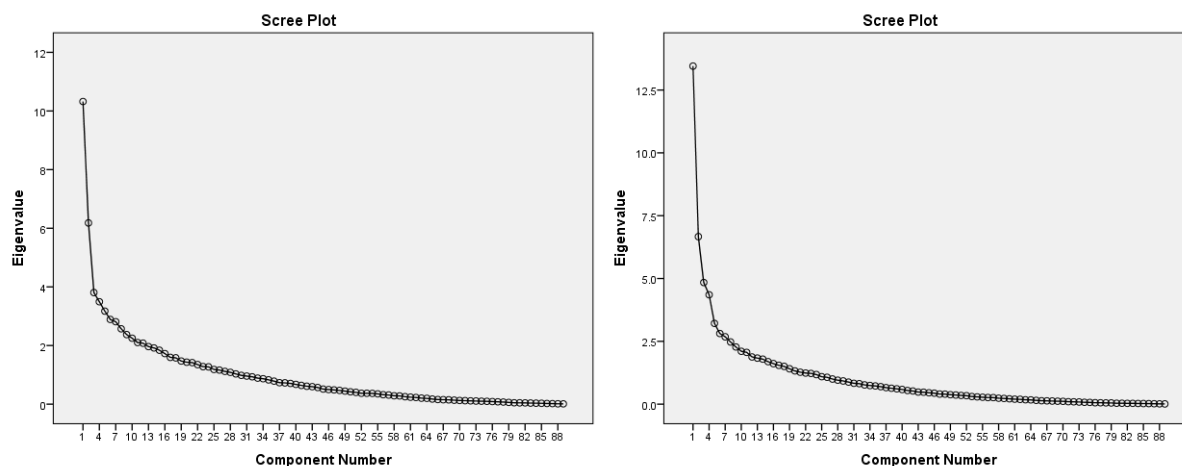
Figure 21: Scree plots for exploratory factor analyses on the pre (left) and post (right) responses to the PATT survey

Table 14: Eigenvalues, explained variance and cumulative explained variance of the five factors for the pre-test sample

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Eigenvalue	10.322	6.181	3.806	3.493	3.173
Proportion of explained variance	11.598	6.945	4.276	3.925	3.565
Cumulative explained variance	11.598	18.544	22.820	26.745	30.310

Table 15: Eigenvalues, explained variance and cumulative explained variance of the five factors for the post-test sample

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Eigenvalue	13.453	6.666	4.841	4.354	3.215
Proportion of explained variance	15.116	7.490	5.439	4.892	3.612
Cumulative explained variance	15.116	22.605	28.044	32.936	36.548

The next stage of the analysis was to develop a factor model with sufficiently high internal reliability within each factor. While the EFA results suggested a 5 factor model, previous study conducted by Ardies et al. (2009) and Bame and Dugger Jr (1989) suggest a 6 factor model. Based on these results, a second round of EFA were conducted on both data sets however this time both a 5 and 6 factor model was specified to be retained. An oblique promax rotation was specified for these analyses. The resulting Cronbach's Alpha values are illustrated in Table 3 below.

Table 16: Cronbach's Alpha values for each factor in the 5 and 6 factor solutions for the pre and post-test samples

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Pre Test 5 Factors	0.887	0.798	0.803	0.333	0.511	
Post Test 5 Factors	0.909	0.861	0.675	0.733	0.660	
Pre Test 6 Factors	0.879	0.646	0.775	0.286	0.388	0.382
Post Test 6 Factors	0.901	0.86	0.701	0.733	0.561	0.651

An observation of the Cronbach's Alpha values illustrated in Table 3 identifies higher internal reliability within factors which emerged from the post-test dataset. Due to the participants' engagement with ITTE modules between administrations of the PATT tool it is posited that their conceptions of technology evolved during this time which resulted in the intrinsic clarification in

their associated attitudes. Stemming from this conjecture the post-test dataset was utilised within the subsequent confirmatory factor analysis.

A number of factor models were run through a confirmatory factor analysis. Both the 5 and 6 factor structures that were revealed through the earlier exploratory factor analyses were initially tested. These were examined both with and without latent variables correlating. The results showed that a 5 factor model with correlating latent variables was the best fit. A number of iterations were subsequently examined with alternations made based on resulting Cronbach's Alpha values for each factor based on the removal of test items. Fit indices of each examined model are presented in Table 4.

Table 17: Fit indices of CFA models

	χ^2	DF	RMSEA	CFI	AIC
5 Factors: Latent variables uncorrelated	3072.159	1652	0.088	0.56	3426.159
5 Factors: Latent variables correlated	3004.66	1642	0.086	0.578	3378.66
6 Factors: Latent variables uncorrelated	3385.329	1829	0.087	0.543	3757.329
6 Factors: Latent variables correlated	Undefinable due to sample size limitations or very poor model fit				
Below based on 5 Factors with latent variables correlated					
Q21 Loading on F5	2984.795	1641	0.086	0.584	3360.795
Q21 Loading on F5 and Q9 Loading on F1 and F2	3118.332	1699	0.086	0.57	3500.332
Removed Q24, Q60 and Q61	2764.293	1710	0.085	0.597	3128.293
Removed Q9, Q24, Q60 and Q61	2652.575	1474	0.084	0.606	3008.575

The fit indices shown in Table 4 illustrate that no model meets the critical values required (CFI>.95; RMSEA<.05). The final model inspected, the 5 factor model with latent variables correlated and items Q9, Q24, Q60 and Q61 removed was the closed to reaching these values. The Cronbach's Alpha values for the factors in this model are illustrated in Table 5 and CFA model is illustrated in Figure 2.

Table 18: Cronbach's Alpha values for final model

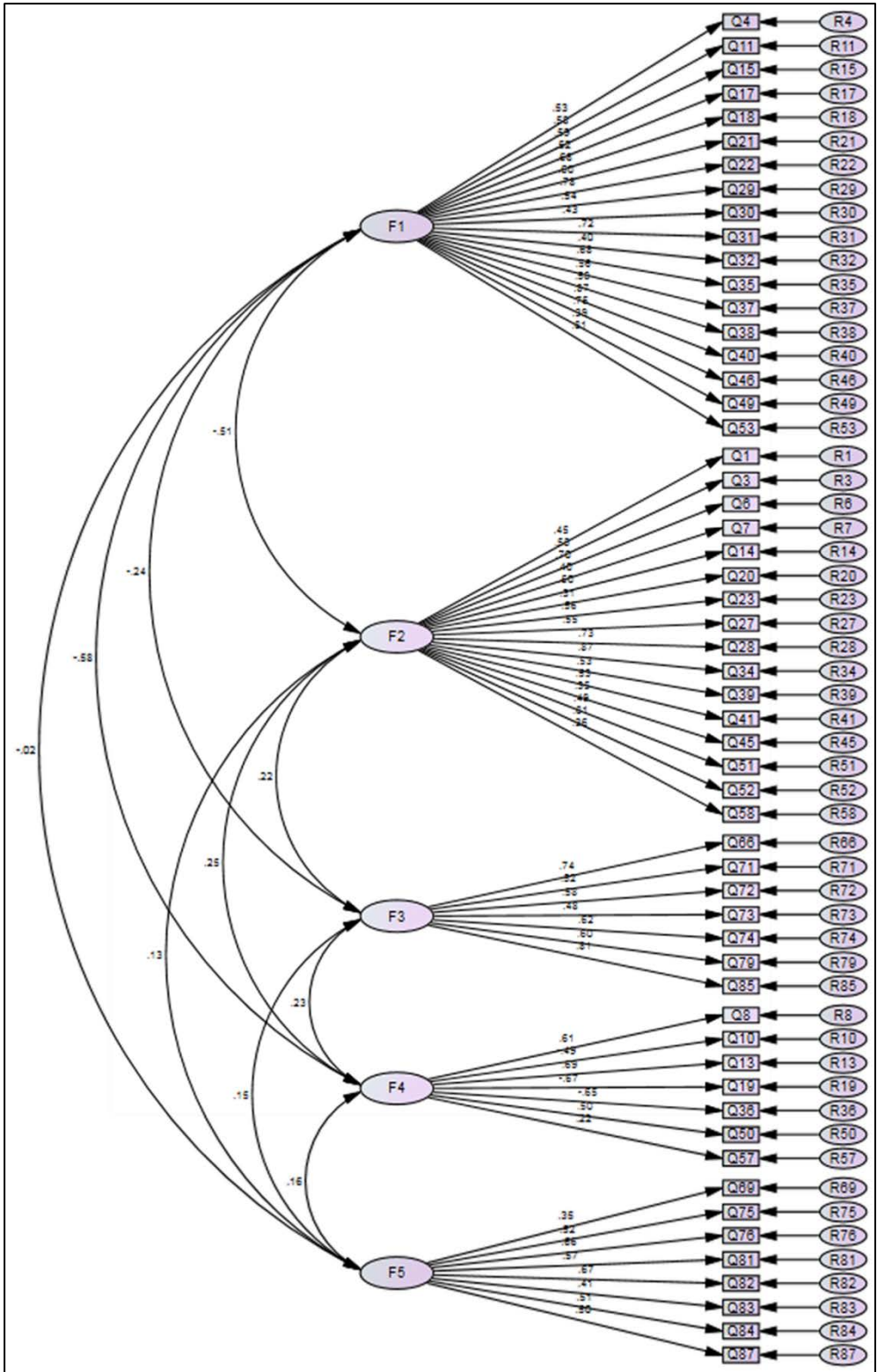|	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Cronbach's Alpha	0.909	0.861	0.787	0.708	0.732

Figure 22: CFA model of best fit

Factor Interpretation

Upon ascertaining the model of best fit, the final stage of the analysis involved interpreting the factors based on the included items. While typically this would be an intrinsic element to the quantitative modelling, it was decided at this stage to separate the factor interpretation from the CFA modelling as the intent of this study was not to generate a final model as this analysis will be repeated when additional data is gathered. An observation of the items loading on each yields tentative factors identified in Table 6. As factor interpretation is based on researcher inference, a

selection of sample items loading on each factor is included. As previously mentioned the CFA model is considered tentative. In order to allow for further refinement in the next round of testing a comparatively large number of items were retained. Given the pilot nature of the current study the factor labels in Table 6 are considered by the authors to be suggestive of future refinement directions as opposed to complete. Cognisant of the non-finalised version of the factor structure; comparatively low face validity when compared to more refined versions (Ardies et al. 2009) is acknowledged. This reduction in face validity is accepted in order to allow for greater levels of plasticity in future versions primarily informed by the EFA outlined previously.

Table 19: Factor descriptions and sample items

Factor	Description	Example Items
1	Technology in education and the economy	I believe there is too much of a focus on technology education in schools. I believe technology should be covered less at second level. I do not understand why anyone would want a job in technology. The world would be a better place without technology. Using technology makes a country less prosperous. Working in technology would be boring.
2	Interest towards technology	When something new is discovered, I want to know more about it immediately. If I was to change career could see myself working in a technology related job. If there was a technology club/society I would certainly join it. There should be more education about technology. Working in technology would be interesting.
3	Affordances of technology	In technology you can think up new things. Technology has a large influence on people. I think technology is often used in science. In everyday life, I have a lot to do with technology.
4	Technology and Gender	A female can perform well in a technology subject. A female can become a car mechanic. Males are more suited to practical subjects than females. Males are more capable of performing technological jobs than females. Everybody can study technology.
5	Limited conceptions of technology	In technology there is little opportunity to think up things yourself. When I think of technology I mainly think of computer programs. Only technicians are in charge of technology. Technology has always to do with mass production. In technology there are less opportunities to do things with your hands.

Discussion

The pilot stage of the redevelopment of the PATT instrument towards a more focused derivative suggests that the more concise version of the instrument will also yield a more reliable format. In addition, the updates to media references and the increased relevance of the more focused version do not appear to have negatively impacted the reliability of the instrument. It is important to note that the results highlighted as sub optimal in the previous section have been linked to the

relatively small sample size. At this pilot stage of the redevelopment these limitations are considered acceptable but they highlight the need for future larger scale applications.

The factor analysis used supports the views of Osborne, Simon and Collins (2003) who posited that attitudes towards a particular subject consist of multiple sub factors. This is further supported by the findings of Ardies et al. (2009) who conducted a similar redevelopment with a greater sample size. In contrast to Ardies et al. (2009) the model of best fit in this study was found to consist of five factors as opposed to six. The internal consistency of the five factors ranged from .732 to .909. Interestingly although Ardies et al. (2009, p.17) utilised a six factor model one of the identified factors was found to have "dubious" internal consistency.

The factors emerging for this study are similar to those retained in the studies conducted by Ardies et al. (2009) and Bame and Dugger Jr (1989). All studies identify factors pertinent to gender equity in technology, interest in technology and consequences of technology. Minor deviations are seen in factors associated with attitudes towards technology and the difficulty of technology but this likely stems from researcher inference in naming the factors. The emergence of similar factors across these studies suggests a high degree of validity in its underlying structure. As such, these factors merit recognition in the progression of this research avenue towards the creation of a tool designed to elicit attitudes towards technology education.

Conclusion

Given the often difficult nature of assessment that focuses on affective learning outcomes, the PATT tool provides a useful indicator of attitudinal change pertinent to technology. As discussed at the beginning of this paper there is an international drive to increase the use of technology in all classrooms. This highlights the need for teacher educators to be aware of the impact of attitudinally targeted learning outcomes.

With the longitudinal agenda of creating a tool with the capacity to validly gather attitudinal perspectives towards the entire spectrum of technology education, this study has offered a significant perspective in the specific area of attitudes towards technology. With the wide array of factors within technology education, the design of such an instrument warrants a clear factor structure with strategically selected appropriate items. The results of this study coupled with other similar studies identify a number of clear factors and items within this context for this purpose. Concurrently, from the perspective of a practitioner, the development of this tool would offer a more accessible way of determining their students pertinent attitudes thus facilitating the attainment and assessment of attitudinally targeted learning outcomes.

Reference List

Albarracin, D., Zanna, M., Johnson, B., & Kumkala, G. (2005). Attitudes: Introduction and Scope. In D. Albarracin, B. Johnson, & M. Zanna (Eds.), *The Handbook of Attitudes* (pp. 3–19). New Jersey: Lawrence Erlbaum Associates, Inc., Publishers.

Ardies, J., de Maeyer, S., & Gijbels, D. (2009). Reconstructing the Pupils Attitude Towards Technology-survey. *Design and Technology Education: An International Journal*, *18*(1), 8–19.

Bame, E., & Dugger Jr, W. (1989). *Pupils' Attitude Toward Technology - PATT-USA Report Findings*.

Bame, E., Dugger Jr, W., de Vries, M., & McBee, J. (1993). Pupils' Attitude Toward Technology - PATT-USA. *Journal of Technology Studies*, *19*(1), 40–48.

Buabeng-Andoh, C. (2012). Factors Influencing Teachers' Adoption and Integration of Information and Communication Technology into Teaching: A Review of the Literature. *International Journal of Education & Development Using Information & Communication Technology*, *8*(1), 136–155.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). Oxfordshire, England: Routledge.

Dawes, J. (2008). Do Data Characteristics Change According to the Number of Scale Points Used? An Experiment Using 5-Point, 7-Point and 10-Point Scales. *International Journal of Market Research*, *50*(1), 61–77.

de Vries, M. (1988). *Techniek in het Natuurkunde-Onderwijs*. Technische Universiteit Eindhoven.

Hattie, J. (2008). *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. London: Routledge.

Krathwohl, D., Bloom, B., & Bertram, B. (1964). *Taxonomy of Educational Objectives: Handbook II. Affective Domain*. New York: David McKay Company Inc.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes Towards Science: A Review of the Literature and its Implications. *International Journal of Science Education*, *25*(9), 1049–1079.

Pink, D. (2005). *A Whole New Mind: Why Right-Brainers Will Rule the Future*. New York: Penguine Group (USA) Inc.

Wittink, D., & Bayer, L. (1994). The Measurement Imperative: Empirical Results on the Number of Scale Points Give Managers a Reliable Gauge for Assessing Customer Satisfaction. *Marketing Research6*, *4*(9), 14–22.

Exploration of 21st Century Skills That Might Be Delivered Through Technology Education

Ritz, John
Old Dominion University, Norfolk, VA, USA
jritz@odu.edu

Bevins, P. Scott, University of Virginia at Wise, Wise, VA, USA
s_bevins@uvawise.edu

Abstract

Content analysis is a unique tool for making statistical comparisons of concepts. In this study it was a tool used to compare the skills that government and industry believe youth need for education and work in the 21st century compared with the goals technology education professionals embellish in program development and assessment. The researchers hope to show that technology education programs in primary and secondary education are providing 21st century skills for learners who complete these studies. Comparisons were made between a summarized list of 21st century goals and those formulated for technology education in England, New Zealand, Sweden, plus goals generated through research methods by Ritz (2009) in the US. It was found that technology education goals compared favorably with those sought by business and government in digital-age literacy and inventive thinking. Shortcomings exist with a lack of goals for effective communication and high productivity results.

Introduction

Technology education has developed over the past 50 years from a skills-based school subject that focused on tool usage and product making that assists learners with future employment to a program for studying technological literacy that develops technological problem-solving skills through hands-on project designs. This program change has occurred in countries and regions around the world. Different approaches have been researched, developed, presented, tested, and modified. In the US, technology became a content-based discipline and a structure was established for studying communication, production, and transportation technologies. Researchers/philosophers believed that the study of general technology was more important than the development of tool and material usage skills. More recently, engineering design has been used as an instructional strategy for applying the systems of technology.

England's technology educators believe the development of design concepts and skills were as important as developing project making skills for learners. The teaching of design technology emerged and this concept has been researched, developed, implemented, and assessed. Both of these curriculum focuses, systems of technology and design technology, have spread to countries that are interested in the redesign of technology education. Today countries are developing technology education programs that include these contents and skills.

Recent analyses of education by government and industry on the preparation of students and workers for the 21st century have proposed schooling outcomes that graduates and workers should master. Some proposals for changes to the way we should educate youth include *Framework for 21st Century Learning* (The Partnership for 21st Century Skills, 2007), *Four Keys to*

College and Career Readiness (Conley & the Educational Policy Improvement Center, 2011), and *Seven Survival Skills* (Wagner & The Change Leadership Group at the Harvard Graduate School of Education, 2008). Although many of these proposals focused on educational system changes, much of the impetus for these changes have been proposed because of lagging international economic development and the need for workers to fill the demand for STEM-skilled occupations.

Technology education programs have changed in many countries during the past 50 years. These changes have been planned and have developed from research and experimentation. However, have these changes assisted students who have recently completed these studies to better understand the technological world in general? Have the changes aiming at technological literacy increased or reduced the repertoire of skills needed for careers after secondary and tertiary schooling?

Research Questions

The intent of this study was to determine if international professional thinking and practice in technology education is in line with educational expectations of government and industry. To analyze this problem, the following research hypothesis was tested.

H_0: There are no significant differences between the empirical goals proposed by technology education professionals and the knowledge and skills identified by government and industry groups for the preparation of youth for the 21st century.

Literature Review

Studies have been undertaken to determine what knowledge and skills youth need in the 21st century to enable them and their economies to progress. The Metiri Group (2010), a policy analysis think tank, summarizes a number of studies including *Framework for 21st Century Learning* (The Partnership for 21st Century Skills, 2007), *Four Keys to College and Career Readiness* (Conley & The Educational Policy Improvement Center, 2011), *Seven Survival Skills* (Wagner & The Change Leadership Group at the Harvard Graduate School of Education, 2008), and other studies (e.g., *Standards for Technological Literacy: Content for the Study of Technology* (ITEEA, 2000); *Technically Speaking: Why All Americans Need to Know More About Technology* (National Academy of Engineering and National Research Council, 2002) and it recommends what students needed to possess to be successful in the 21st century. The Metiri Groups categorized these skills as *digital age literacy skills*, *inventive thinking skills*, *interactive communication skills*, and *produce quality state-of-the art results*. This group believes these skills are needed to maximize a student's success in the 21st century, both educationally and economically. See Figure 1 for a listing of these skills and their subsets.
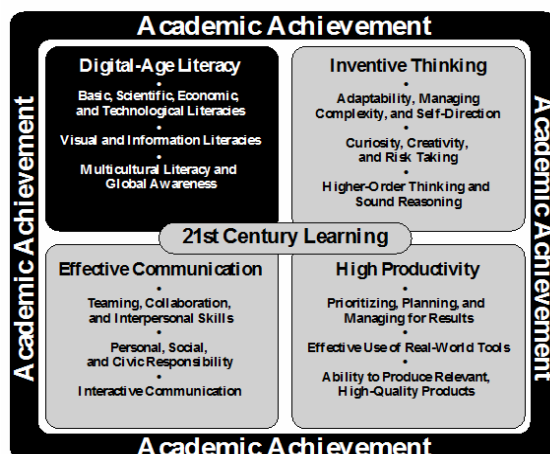
Figure 1. Metiri Group Skills for the 21st Century. Retrieved from: www.ncrel.org/engauge

Throughout the history of technology education, and its predecessor industrial arts, individuals and groups have established goals for guidance in the development of these school programs. Because many of these goal sets were developed by individuals or professional groups, and not developed using research methods, Ritz (2009) undertook a Delphi study, using all of the boards of the International Technology and Engineering Educators Association (*N* = 33; all elected officials), to develop an agreed upon list of goals for this school subject. This four round Delphi study produced the following set of program goals for technology education.

- Describe social, ethical, and environmental impacts associated with the use of technology.
- Become educated consumers of technology for personal, professional, and societal use.
- Apply design principles that solve engineering and technological problems.
- Use technological systems and devices.
- Use technology to solve problems.

In this current study, it was important to see if the goals developed by Ritz (2009) aligned with others, those developed in other countries, so the list could be validated and used for comparative analysis to the skills government and industry believed were important for learner education and workforce preparation for the 21st century. Technology education goals that were developed in England, New Zealand, and Sweden will be described to see how they compare with the goals Ritz (2009) developed with the assistance of the International Technology and Engineering Educators Association. These groups of goals will then be compared with those outcomes sought by government and industry as expressed through the Metiri Group study for 21st century learners (2003).

In England, the Department of Education lists the following set of goals for the development of Design and Technology programs. These include:

- Develop the creative, technical and practical expertise needed to perform everyday tasks confidently and to participate successfully in an increasingly technological world.
- Build and apply a repertoire of knowledge, understanding and skills in order to design and make high-quality prototypes and products for a wide range of users.
- Critique, evaluate and test their ideas and products and the work of others.
- Understand and apply the principles of nutrition and learn how to cook. (Department of Education, 2013)

The first three of these outcomes appear to align with the goals developed by Ritz (2009). The one outcome that is not aligned is the one seeking nutrition and cooking knowledge. Food and textiles are materials areas that professionals in design and technology have included in the curriculum in English schools, since practiners do design using these materials.

In New Zealand, educators developed the following outcomes to guide program development in their country's technology education programs. Learners:

- have a broad understanding of how and why things work.
- understand how technological products and technological systems are developed.
- can critically evaluate technological developments and trends.

- can design and evaluate their own solutions in response to needs and opportunities. (Minister of Education, 2015)

Again these outcomes appear to align well with the goals that Ritz (2009) developed using research methodologies in the US.

In Sweden, the outcomes that are used to guide their program developments and assessments include:

- Identify and analyse technological solutions based on their appropriateness and function.
- Identify problems and needs that can be solved by means of technology, and work out proposals for solutions.
- Use the concepts and expressions of technology,
- Assess the consequences of different technological choices for the individual, society and the environment.
- Analyse the driving forces of technological development and how technology has changed over time. (Skolveret, 2011)

Again these outcomes appear to be in line with those of other countries and the study conducted by Ritz (2009). Therefore the researchers believed that for the four countries discussed, the outcomes appear consistent for the school programs of technology education.

Methodology

Content analysis was used to analyze the skills projected by the four countries selected in this study. Other country goals could have been selected, but the researchers selected to study these four since they were familiar with the research currently being undertaken in technology education in these countries. Quantitative content analysis, or text data mining, uses algorithms to compare key words researchers select to enter into the program. The researchers selected to use free software, *KH Coder*. It uses computational linguistics. In this study, content analysis centered around three aspects relating to the goals or outcomes of technology education: (a) word similarities in the technology education goals or outcomes from England, New Zealand, Sweden, and Ritz's 2009 goals, (b) outcome similarities among the three countries and Ritz's goals, and (c) outcome similarities among the three countries and Ritz's goal research and the Metiri skills for the 21st century. Chi-square analyses were used in comparing each country's goals to the Metiri skills for the 21st century.

Findings

The total 18 goals or outcomes for technology education in England, New Zealand, Sweden, and US (Ritz Study) consisted of 18 sentences (treated as paragraphs in *KH Coder*), totaling 96 words, excluding "common" words, such as "a," "an," "the," and "though." Of the remaining words, each appeared on average 1.40 times, with 78% or 75 words appearing only once. An analysis using "random walks" revealed three similar communities or word groups among the 18 technology education goals, with the terms "technological" and "technology" having the highest frequency, as denoted by their larger node size (bubbles or circles) in Figure 2. While all words within each community were closely associated, as depicted by the solid lines or edges, words most closely associated, as indicated by the thicker edges included: problem and solve, solution and need, solution and identify, and solve and identify. The word most associated with other words was "technology" with 8 edges.
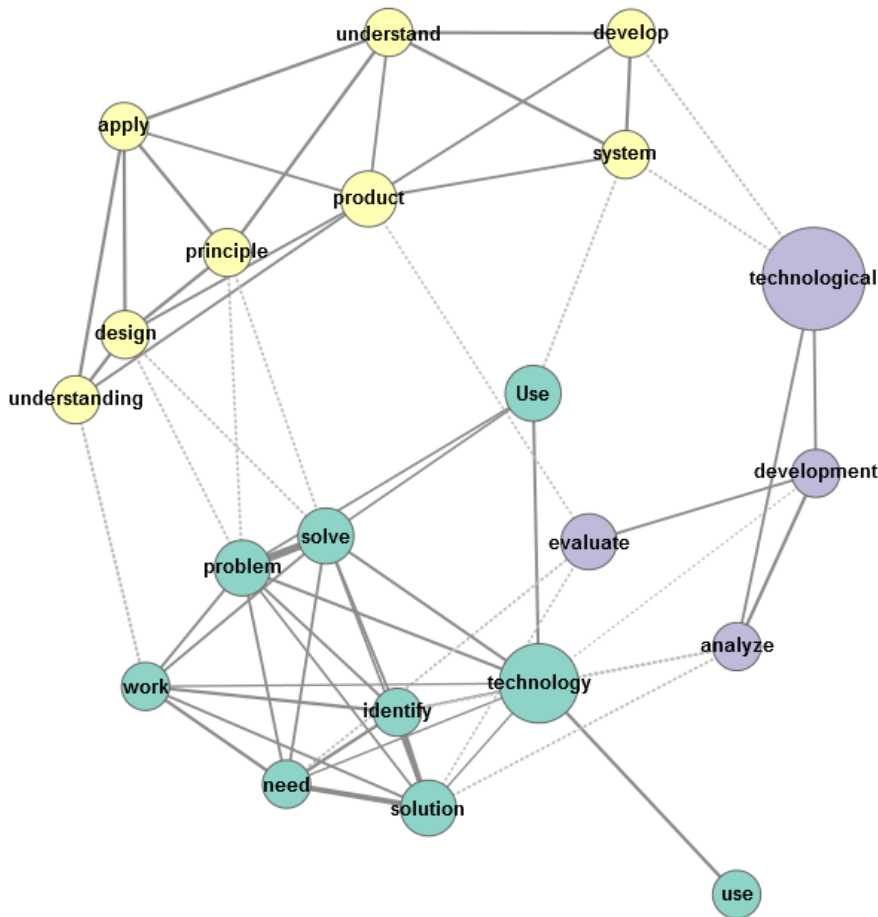
Figure 2. Word Similarities Determined by Random Walks

When the headings or origin of each set of outcomes were included, New Zealand and Sweden had the largest number of edges, that is, technology education goal word associations. New Zealand and Sweden each had 11 and England and Ritz, 9 associations each. Figure 3 and Table 1 identifies the word associations. In addition, how the word is used in the outcome is also indicated in Table 1, with "a" for adjective, "n" for noun, and "v" for verb. Not surprisingly, each was associated with the term "technological". New Zealand and England had the largest number of joint word associations, six: understand, evaluate, develop, product, understanding, and technological. England and Sweden had the fewest, one: technological. The words having no joint associations included, respectively three verbs and one noun: analyze, identify, apply, and use. Interestingly, these four terms are used to define technological literacy in *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000).

The third analysis sought to determine whether the goals or outcomes established by technology education professionals fulfill the knowledge and skills gap identified by government and industry groups for the preparation of youth for the 21st century as hypothesized. The analysis utilized a cross-tabulated heat map (frequency is indicated using a gradient color scale, hence, wherever a code appears frequently it has a darker color) and the chi-square test. The heat map revealed the percentage of outcomes from each respective source, England, New Zealand, Sweden, and Ritz that contained code words from the 21st century skillsets (digital age literacy, inventive thinking, effective communication, and high productivity). The chi-square test was used to determine whether there were significant differences among the outcomes for each skillset.
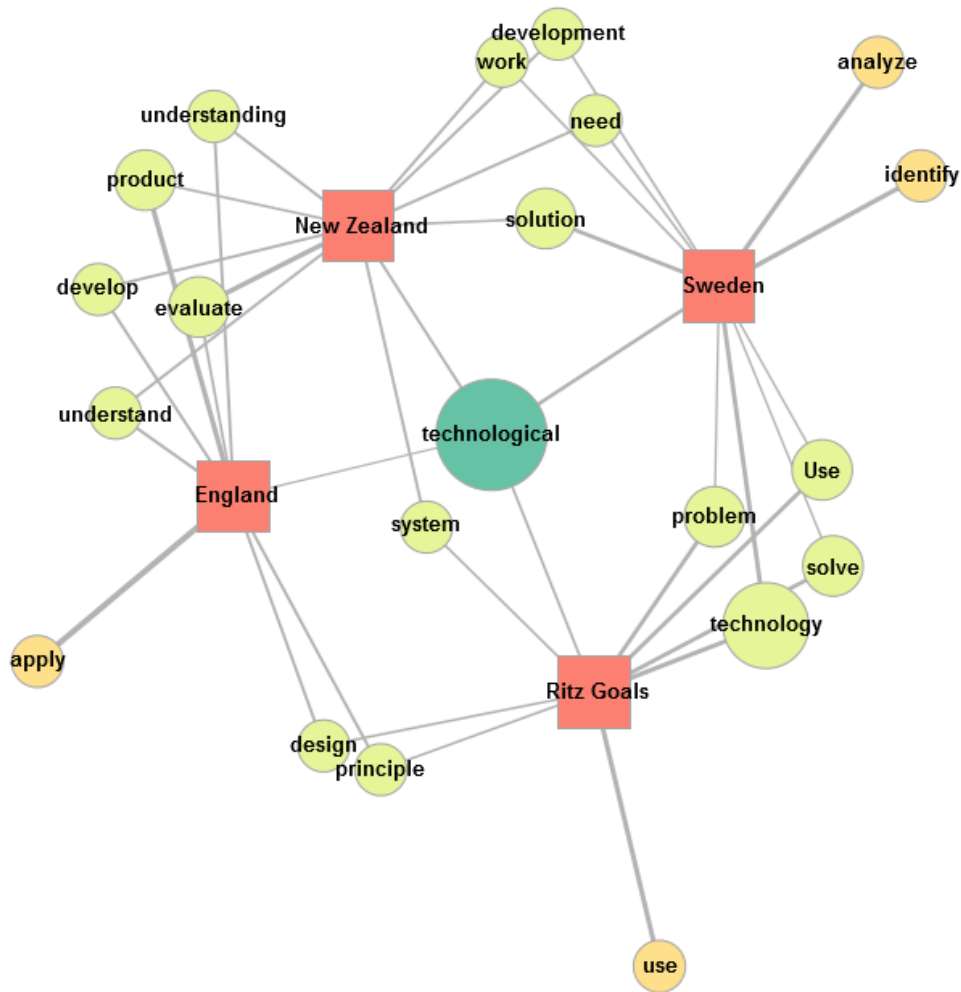
Figure 3. Word Similarities by Outcome Sources

As shown in Table 1 and Figure 4, the code words from the *inventive thinking* skillset were found in more outcomes for England, New Zealand, and Ritz, than code words from the other three skillsets. In fact, 12 of the 18 outcomes contained code words from the *inventive-thinking* skillset, followed by the *digital age literacy* skillset with nine, *high productivity* with six, and *effective communication* with four. Sixty percent or three out of four of England's outcomes contained code words from the *inventive thinking* skillset, while two out of five or 40% of the outcomes contained code words in each of the remaining skillsets. Fifty percent or two out of four of New Zealand's outcomes contained *inventive thinking* code words, with one out of four or 25% of the outcomes contained code words from the remaining skillsets. Eighty percent or four out of five of Ritz's outcomes contained code words from the *inventive thinking* skillset, and three out of five outcomes contained code words from the *digital age literacy* skillset. Sweden had more of its outcomes containing code words from the four skillsets. Eighty percent of its outcomes had code words from the *digital age literacy* skillset, 80% from *high productivity*, 60% from *inventive thinking*, and 40% from *effective communication*.

Table 1

Word Associations by Outcome Sources

	Ritz	New Zealand	Sweden
England	▪ Design (n) ▪ Principle (a) ▪ *Technological* (a)	▪ Understand (v) ▪ Evaluate (v) ▪ Develop (v) ▪ Product (n) ▪ Understanding (n) ▪ *Technological* (a)	▪ *Technological* (a)
Sweden	▪ Problem (n) ▪ Use (v) ▪ Solve (v) ▪ Technology (n) ▪ *Technological* (a)	▪ Solution (n) ▪ Need (n) ▪ Work (n) ▪ Development (n) ▪ *Technological* (a)	
New Zealand	▪ System (n) ▪ *Technological* (a)		

Note: "a" denotes adjective; "n" denotes noun; and "v" denotes verb.

Chi-square tests were performed to determine whether the outcomes for each source contained code words in each skillset or whether each outcome was independent of the others, not reflecting each skillset. However, in testing, each outcome was expected to align with each skillset, indicating that each outcome would contain the code words needed to align it with each respective skillset. According to the chi-square test statistics for each country as shown in Table 2, there was no significant difference in the number or percentage of outcomes related to each respective skillset; therefore, the null hypotheses were not rejected for alpha levels of 0.05. There was no specific alignment between a country's outcome and a skillset. With respect to England, the results indicated that the test was not significant X^2 (3, $N = 4$) = 7.00, X_α = 7.82, and the specific outcomes per skillset were similar. Only one of four outcomes aligned with three of the skillsets, *digital-age literacy*, *effective communication*, and *high productivity*, as shown in Table 3. In regards to New Zealand, the results indicated that the test was not significant X^2 (3, $N = 4$) = 7.75, X_α = 7.82, and the specific outcomes per skillset were similar. For Sweden, the results indicated that the test was not significant X^2 (3, $N = 4$) = 3.00, X_α = 9.49, and the specific outcomes per skillset were very similar. While Ritz's outcomes containing code words in each skillset were significantly different for α = 0.05. That is, the results indicated that the test was significant X^2 (3, $N = 4$) = 11.00, X_α = 9.49, and the outcomes per skillset were not very similar for an alpha level of 0.05. To address the possibility of upward bias, results being larger than they should be because of small sample sizes, Yate's chi-square tests were conducted as well. As shown in Table 2, Yate's chi-square test results provided further evidence in support of the findings from the chi-square tests.
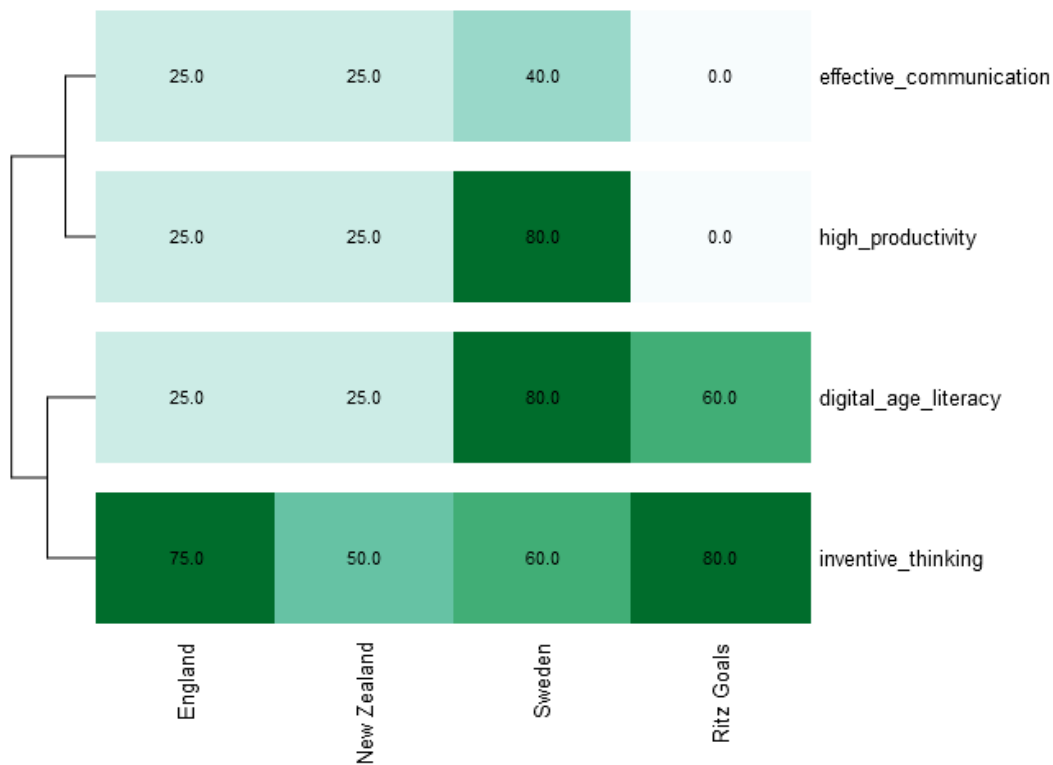
Figure 4. Technology Education Outcomes Categorized According to 21st Century Skills

Table 2

Technology Education Outcomes by Skillset Alignment with Metiri

	England	New Zealand	Sweden	Ritz
Digital Age Literacy	1 (25.00%)	1 (25.00%)	4 (80.00%)	3 (60.00%)
Inventive Thinking	3 (75.00%)	2 (50.00%)	3 (60.00%)	4 (80.00%)
Effective Communication	1 (25.00%)	1 (25.00%)	2 (40.00%)	0 (0.00%)
High Productivity	1 (25.00%)	1 (25.00%)	4 (80.00%)	0 (0.00%)
Number of Outcomes	4	4	5	5
Chi-Square	7.00	7.75	3.00	11.00*
Yate's Chi-Square	4.75	5.25	1.80	8.60
Critical Value	7.82	7.82	9.49	9.49*

*Significant for $\alpha = 0.05$

Conclusions

When one first looks at the goals established by the different countries for technology education, many appear to be focused on the same outcomes. Content analysis shows that there are some distinctions among the program goals. The most common terms are *technological* and *technology*. This is no surprise because the country program goals were designed to study technological literacy as an overall aim for educating their learners. When the null hypotheses were statistically analyzed using chi-squares, there were significant relationships between the empirical goals proposed by technology education professionals in England, New Zealand, and Sweden and the knowledge and skills identified by government and industry groups for the preparation of youth for the 21st century. The researchers found technology education program outcomes do not totally align with the projected needs of governments and businesses, $p < .05$. Although there is strong alignment with digital-age literacy and inventive thinking, all counties but Sweden lacked development of *effective communication* skills. Sweden's goals were the most aligned with the student's needs for the 21st century as shown in the data reported in Table 3. The US lacked outcomes directed toward the *effective communication* and *high productivity skillsets*.

Table 3
Technology Education Outcome Alignment by Source and Skillset Defined by Metiri

Outcome	Digital Age Literacy	Inventive Thinking	Effective Communication	High Productivity
England:				
• Develop the creative, technical, and practical expertise needed to perform everyday tasks confidently and to participate successfully in an increasingly technological world.		✓		✓
• Build and apply a repertoire of knowledge, understanding and skills in order to design and make high-quality prototypes and products for a wide range of users.		✓		
• Critique, evaluate and test their ideas and products and the work of others.		✓	✓	
• Understand and apply the principles of nutrition and learn how to cook.	✓			
New Zealand:				
• Have a broad understanding of how and why things work.			✓	
• Understand how technological products and technological systems are developed.	✓			
• Can critically evaluate technological developments and trends.		✓		
• Can design and evaluate their own		✓		✓

solutions in response to needs and opportunities.

Sweden:

• Identify and analyze technological solutions based on their appropriateness and function.				✓
• Identify problems and needs that can be solved by means of technology, and work out proposals for solutions.	✓	✓	✓	✓
• Use the concepts and expressions of technology.	✓	✓		
• Assess the consequences of different technological choices for the individual, society and the environment.	✓		✓	✓
• Analyze the driving forces of technological development and how technology has changed over time.	✓	✓		✓

Ritz (2009 Article):

• Describe social ethical and environmental impacts associated with the use of technology.	✓	✓		
• Become educated consumers of technology for personal, professional, and societal use.	✓	✓		
• Apply design principles that solve engineering and technological problems.		✓		
• Use technological systems and devices.				
• Use technology to solve problems.	✓	✓		

Note: Some goals align but not all technology education goals meet the subsets of goals of government and industry.

Recommendations

As several of the individual country hypotheses were accepted, technology education appears to contribute to the needs of 21st century learners. To better serve students, the technology education community should revisit its goals for learners and possibly re-design some of its goals. Changes might be made to better prepare students for the 21st century through the study of technology education. Further research could be undertaken to compare goals for technology education for additional countries and also further investigate if the goals for 21st century learners also need to be modified by governments and businesses.

References

Conley, D., & The Educational Policy Improvement Center. (2011). *Four keys to college and career readiness*. Eugene, OR: The Educational Policy Improvement Center. Retrieved from: http://knowledgecenter.csg.org/kc/system/files/conleyPDF.pdf

Department of Education. (2013). National curriculum in England: Design and technology programmes of study. Retrieved from: https://www.gov.uk/government/publications/national-curriculum-in-england-design-and-technology-programmes-of-study/national-curriculum-in-england-design-and-technology-programmes-of-study#key-stage-3

International Technology Education Association (ITEA). (2000). Standards for technological literacy: Content for the study of technology. Reston, VA: Author.

METIRI Group in partnership with The North Central Regional Laboratory. (2010). Retrieved from http://enGauge.ncrel.org and www.metiri.com. These skills resulted from their meta-analysis of other skill reports. The full report can be retrieved from http://ncrel.engauge.org.

Minister of Education. (2015). Technology in the New Zealand curriculum. Retrieved from: http://technology.tki.org.nz/Technology-in-the-NZC

National Academy of Engineering and National Research Council. (2002). Technically speaking: Why all Americans need to know more about technology. Washington DC: National Academies Press. Retrieved from: www.nap.edu/books/0309082625/html/

Ritz, J. M. (2009). A new generation of goals for technology education. *Journal of Technology Education, 20*(2), 50-64*.*

Skolveret. (2011). *Curriculum for the compulsory school, preschool class and the leisure-time centre 2011*. Stockholm, Sweden: Author. Retrieved from: www.skolverket.se/publikationer

The Partnership for 21st Century Skills. (2007). *Framework for 21st century learning.* Washington, DC: Author. Retrieved from: http://www.p21.org/our-work/p21-framework

Wagner, T., & The Change Leadership Group at the Harvard Graduate School of Education. (2008). *Seven survival skills*. Cambridge, MA: Author. Retrieved from: http://www.tonywagner.com/7-survival-skills

Developing 21st Century Skills in Swedish Compulsory School Technology Education: Three Teacher Perspectives

Patrick Schooner.
Linköping University
Norrköping, Sweden,
patrick.schooner@liu.se.

Charlotta Nordlöf,
Linköping University,
Norrköping, Sweden,
charlotta.nordlof@liu.se.

Claes Klasander
Linköping University,
Norrköping, Sweden,
claes.klasander@liu.se.

Jonas Hallström
Linköping University,
Norrköping, Sweden, ,
jonas.hallstrom@liu.se.

Abstract

The concept of 21st century skills has several definitions. Sweden, as well as other countries, address 21st century skills under various labels in technology education, especially in terms of competencies connected to technological literacy. However, regardless of used definition, two of the most occurring items concern problem solving and critical thinking. Previous research in the field of technology education lacks descriptions of the relationship between 21st century skills and teaching about technology within the compulsory school system. By investigating Swedish compulsory school technology teachers' views on problem solving and critical thinking capabilities, this study aims at identifying different aspects of the relationship between technology education and 21st century skills. Through the use of in-depth qualitative interviews, this study was able to determine different teacher perspectives addressing problem-solving and critical thinking activities in a classroom environment. The study also explored how the 21st century skills of critical thinking and problem solving were dealt by the teachers and how they perceived that the skills were implemented in their teaching. Additionally, the study shows that the interviewed teachers expressed utilised three perspectives on teaching about technology in a critical thinking and problem solving mode. These were; (1) the artefact driven perspective, (2) the system perspective, and (3) the holistic perspective. In conclusion, even though the present Swedish curriculum does not explicitly mention 21st century skills, the teachers incorporate critical thinking and problem-solving in different settings within the subject of technology. The authors found that the teachers mix the perspectives depending on the teaching content, especially when teaching about complex technology.

Introduction

The OECD (2013) presented central documents defining their views on necessary skills for 21st century citizenship and life-long learning, promoting a generic skill set of literacy, numeracy, and problem solving in technology-rich environments. Others definitions include critical thinking as a vital 21st century skill (Binkley et al., 2012).

In many countries, these skills are already addressed in technology education as a part of the core subject matter, especially regarding competencies connected to technological literacy (Jones, Buntting, & de Vries, 2013). Although hidden under different labels, the concept of 21st century skills have been a part of the Swedish curriculum for the compulsory school for the past decades focusing on core abilities like critical thinking and problem solving.

The recent Swedish curriculum for the subject of technology prescribes the identification of problems and finding technological solutions to the identified problems, as well as a critical analysis of modern technology usage and its everyday interaction with people and society (Skolverket, 2011b). As such, technology education can, therefore, be regarded as especially adapted to the challenge of developing skills for 21st century readiness. In a teaching context, this means that students should be taught various methods for thinking and working with adequate technological competencies (Mitcham, 1994; Ropohl, 1997). This presents an interesting possibility to explore the relationship between 21st century skills and technology education from teacher's point of view. This relationship has not been previously studied in technology education research.

Hence, by investigating Swedish compulsory school technology teachers' views on problem solving and critical thinking capabilities, this study aims at identifying different aspects of the relationship between technology education and 21st century skills.

Method

In this paper, the authors interviewed 21 compulsory school technology teachers using a qualitative semi-structured interview guide (Kvale & Brinkmann, 2014). The interviews were conducted at each informant's workplace with their explicit consent and varied between 45 and 90 minutes in duration. The interview guide focused on exploring the teachers' views on their own teaching within the subject of technology, with follow-up questions regarding specific teaching activities that the teachers mentioned during the interviews.

A dataset was chosen from the interviews containing the teachers' own viewpoints on their own teaching about technology when employing aspects of problem-solving and critical thinking. The dataset was then organized and coded with the use of the software called MAXQDA. The analysis followed an interpretive process to derive themes from the dataset. By doing so, the authors employed an analytical model based on the hermeneutical spiral (Alvesson & Sköldberg, 2008) and a six-step process of thematic analysis (Braun & Clarke, 2006). The authors' combined background experience in teaching technology was used to provide the necessary analytical horizon for the interpretative analysis.

The first step of the thematic analysis was to transcribe the interviews. The interpretive process of the hermeneutical spiral was later enabled by the authors by repeatedly reading the material (Alvesson & Sköldberg, 2008).

The second step of the process involved an initial coding of interview transcripts using the software MAXQDA. Excerpts of texts were coded using a hermeneutical interpretive approach. Whenever the informants mentioned their teaching practice, the excerpts were coded with a descriptive code label.

The third step continued with a multitude of derived codes that underwent a sorting process to order them into a tree-structured hierarchy. Three categories were constructed by merging codes that were near or overlapping to each other.

The fourth step required the themes to be reviewed, revised and refined to minimize the overlap between the themes. The highlighted themes for the technology teachers' narratives were later discussed and confirmed amongst other peers within technological education research.

The fifth step commenced with the definition and naming of the three key themes, bringing forth the essence of each theme and what aspects of the data they cover: (1) The artefact-driven perspective (design and construction of technology), (2) The system perspective (the complex and networking structure of technology), (3) The holistic perspective (the social and technological implications of technology, on the individual, society and environment). Each category also contained five underlying sub-items.

The sixth step involved presenting exemplary data to each theme as part of this study's results from the thematic analysis. Particularly illustrative quotes were also translated into English and abridged by the authors in order to increase readability.

Findings

The thematic analysis provided three categories of teaching perspectives that promote particular critical thinking and problem solving skills, according to the teachers in this study. The first category centres on an artefact-driven perspective, focusing on the design and construction of technology. The second category revolves around a system perspective, concentrating on the complex and networking structure of technology. The main focus of the third category is the holistic perspective, converging on the social and other implications of technology. Each category also provided several sub-items that together defined the specific theme.

Category	Items	Description
The artefact-driven perspective (design and construction of technology)	• Creativity and idea generation • Drawing and illustration • Construction • Iterative work-methods • Presentation	The abilities to design and construct technological artefacts through a number of activities; (a) By generating ideas from understanding the needs or problems for technological development to form the basis for a technological solution. (b) By drawing a conceptual representation of the suggested solution. (c) By constructing a conceptual or working model/prototype for the derived solution. (d) By continuously revising the design activities if there is room for improvement in the design process. (e) By presenting the solution, for example, in the classroom as part of an assignment.

Most of the interviewed teachers explained that the ability to produce ideas through creative processes was one of the core abilities that the students had to learn and develop. Diana explained that the capacity to draw and illustrate an idea was an important step in the design process when constructing a physical model. Both Alexander and Felicity mentioned that to construct a working prototype or a physical model includes several stages in the construction process. One of these steps may include an iterative loop, i.e. returning to revise the drawing or even the idea of the construction if the students find potential for improvement. The teachers also saw the activity of presentation as a vital step in the design process, as the students present the outcome of the whole work process to other students – mainly to show that they've managed to fulfil the class assignment but also to receive recognition for their creativity.

Category	Items	Description
The system perspective (the complex and networking structure of technology)	• Black-box • Micro-macro • System interfaces (input/output) • Networking parts and components • Processes	The ability to understand technological systems through a number of viewpoints based on identifying key elements of the system; (a) By observing the physical structure of complex technology, such as technological systems, through opening up the black-box that physically encompasses the system in order to critically investigate the internal structure of the system. (b) By observing a technological solution or a system through its different parts and its whole structure so that the overall functionality is observable. (c) By identifying and observing the interfacing components of technological system to determine how the system interacts with its surrounding, i.e. what enters the system by its input(s) and what exists the system by its output(s). (d) By observing and identifying the networking parts and components within a technological system. (e) By identifying and observing a system's different systems processes' and the impacts on functionality that different parts of the system can produce.

Being able to understand the technical processes as well as how different technological solutions can interact with each other was a core element when teaching about complex technology such as technological systems. The importance of understanding how the parts of a system integrate to a whole is something that Leonard focused on in his teaching. He exemplified this in his interview when he uses the computer as an analogy for a technological system were one essential aspect of understanding is seeing how the computer power supply is distributed within the system. He and other teachers used examples of smaller electricity depended technological systems and how they were related to larger electricity distribution systems. In his teaching, the interfacing aspects of systems provides areas for investigation, especially for students using their problem solving skills to identify possible disruptions of service within a system or in relation with another technological system. Nelson also used the computer as a system model and focused on the need to know the interchanging flow of information between the computer user and the computer machine.The human-machine interfacing provides several important areas for critical analysis, which was something that he further explained when he talked about a systems' outputs and the effects on individuals, society, and the environment. The interchanging processes between different components within a system is something that both George and Kate focused on in their teaching. Peter extends this also to include a revealing opening of the "black box", i.e. the outer exterior of a system. By doing so, the interior of the system becomes accessible to the student for the purpose of critically evaluating the importance of individual components and how they affect the system's processes, and in particular the outputs of the system.

Category	Items	Description
The holistic perspective (the social and technological implications of technology, on the individual, society and environment)	• Then-now-future • Implications on individual, society and the environment • Ethics and values • Comparison and valuing of results • The human agent	The ability to analyse and evaluate technology through a set of inquiring activities; (a). By acquiring a temporal understanding of the technological solution's development through the historical development and future evolution. (b) By identifying the solution's implications on the individual, society and environment. (c) By a value-based questioning of the solution from a moral and ethical viewpoint. (d) By comparing and evaluating different solutions to each other, as well as the results of each solution. (e) By identifying and explaining the role of human in technology as an agent and developer of technology.

Technological change was something that the teachers also found to be a core ability when critically analysing and evaluating technology. Especially the temporal understanding of a technical solution, i.e. historical background, present day status, and the possible future development. Peter made a point of this in his teaching, where the students, after understanding the reason behind a technological solution, also continues to improve their own thoughts about technological development. Quintin found it necessary that the students can discuss implications for society, environment and individuals. This is something that other teachers in this study exemplified with technological malfunctions, such as the filtering within a sewage plant or a fuse in a household fuse box. The social aspects of ethics and moral values were also important according to the teachers. Kate introduced this in her teaching by discussing fairness with her students, for example, if every human has the right to drink filtered clean water. Ursula took it further by making the students question the need for cheap clothing if child labourers manufacture it. Some of the teachers found these kinds of discussions relevant when comparing and evaluating different sorts of technological solutions. In Alexander's and Oscar's teaching, qualitative comparisons of various technological innovations (like bridges, household appliances, and digital technology) were something that they focused on. Additionally, the teachers in this study also included problem-solving discussions about efficiency when comparing different solutions. However, regardless of the characteristics of a technological solution, the teachers also mentioned the importance of recognising the human agent in technology, as Oscar explains in his interview, for instance, that not all technology is automated but controlled by humans. He further developed this thought by saying that humans are the catalyst for technological change as humans define needs and act on them to develop solutions.

Discussion

In this study, the authors examined how technology teachers within the Swedish compulsory school perceived their teaching when incorporating the critical thinking and problem solving capabilities as part of their aims to teach 21st century skills to the students. The analysis showed that the interviewed teachers use different types of technological contexts, in particular through three perspectives; (1) the artefact-driven perspective, (2) the system perspective, and (3) the holistic perspective. An interesting note was that these perspectives were mixed by most of the interviewed teachers when teaching about particular areas of technology. For example, Kate used two of the perspectives when she used the local water-sewage plant as a teaching object and

discussed the system from both a system (focusing on the system's structure and function) and holistic (primarily the system's implications) perspective.

The artefact-driven perspective

Artefacts take up a considerable part of the overall teaching about technology in Sweden (Bjurulf, 2008). This harmonises well with being technologically literate, i.e. being able to understand that technological solutions originate from the designer's ability to identify and transforming needs into ideas and after that into concrete artefacts (Ingerman & Collier-Reed, 2011; Wells, 2013). This also corresponds well with the informants' desire to teach students creative methods for idea generating. Furthermore, the design process adds more value to the expected results if the designer continuously evaluates the work methods and usage of materials when constructing physical models or artefacts (Jones, 1997). As such, being able to communicate ideas and concepts through constructed models is a vital part of being technological literate (Compton, 2013; McCormick, 2006). The teachers also saw other beneficial effects like critical thinking skills, problem solving capability, personal growth and student collegial acceptance when the students were able to display their ability to produce something from a design process. The present Swedish curriculum for the compulsory school, Lgr11, also provides details on the design process that corresponds well with the interviewed teachers' ideas about how they teach (Skolverket, 2011a).

The system perspective

To be able to engage complex technology from critical viewpoints requires a system understanding (Hallström & Klasander, 2016; Ingelstam, 2002; Klasander, 2010; Koski & de Vries, 2013). It was evident from the teacher interviews that the vast physical size of some systems (like national electricity distributions systems) hindered students from achieving a clear view of the system's internal structure. Still, Nelson used the black-box perspective on systems when teaching about how the systems' interfacing components (input and output) could relate to individual(s), society and the environment. Understanding the internal functionality of the system requires a comprehension of the parts of the system, i.e. the components and sub-systems and their connectivity through different processes (Lind, 2001; Svensson, 2011). This is something that Oscar says he promotes in his teaching by using a micro-macro transition when observing a system. Leonard mentioned on a side note that by observing the interconnectivity of systems and subsystems, the students are able to use their problem solving skills to identify potential disruptions in connectivity and their consequences. However, when viewing the curriculum of Lgr11, the guidelines do not explicitly define what aspects of system understanding that the students need to learn in comparison with the previously mentioned design process. For example, the curriculum does not mention explicitly the concepts of input, process and output which are commonly used in the discussion of and critical thinking about technological systems (Klasander, 2010; Svensson, 2011; Tamir & de Vries, 1997).

The holistic perspective

For students to develop problem solving and critical thinking skills and thereby achieve a broader understanding of how technology, individual(s), society and the environment relate to each other, they need a holistic understanding of technology (Keirl, 2006). Holistic understanding of technology is also a central part of the subject of technology in the curriculum of Lgr11, as consequences of technological choices and adaptation of technology for humans are mentioned in the curriculum (Skolverket, 2011a). However, the curriculum does not give any deeper guidelines about how to teach or assess these areas. The analysis shows that the informants' ideas about their teaching align with this part of the curriculum. Technological change as well as implications for individuals, society and environment, are areas that are firmly established in Lgr11, which is also reflected in this study's interviews. Ethics are in the foreground when the teachers present discourses about the consequences of technological choices. Ursula conveys these concerns in her teaching, especially the social impacts of buying cheap clothes from developing countries. She further discusses the consequences for the environment as well as for other individuals. Her main point is that her students need to reflect on how the clothes are

manufactured. Finally, an integral part of teaching holistic understanding is to bring forth the critical analysis of both human and automation aspects of controlling technology, as Oscar emphasised in his interview.

Conclusion

This study showed that the teachers said that they used different teaching objects (e.g. specific artefacts and technological systems) and utilised at the same time different perspectives depending on what was in focus for the moment in their teaching. For example, teaching about certain technological systems such as a water sewage plant involved two of this study's perspectives. This illustrates the multi-faceted character of teaching about technology and that these perspectives are not used exclusively and separated from each other, but rather that the teacher integrates two or all perspectives to establish a nuanced learning environment. Additionally, even though the curriculum does not explicitly mention 21st century skills, the teachers incorporate critical thinking and problem-solving capabilities in diverse settings within the subject of technology.

Implications

This study has shown that technology teachers in Sweden employ different perspectives when teaching about technology; the artefact-driven, the system, and the holistic perspectives on technology. These perspectives can be seen as an extension of the 21st century skills of critical thinking and problem solving from a technological point of view. As such, these three perspectives can be used by teachers when designing teaching about technology with the intention of promoting problem-solving and critical thinking skills. Furthermore, authors and other people designing teaching material for the subject of technology can relate to these perspectives.

Further studies should explore how these perspectives can be used together with scaffolding techniques to improve compulsory school students' conceptual understanding of technology in areas of, for example, sustainable development, design and innovation and technological systems. Also, additional studies should explore how different knowledge areas are taught in the subject of technology using these three perspectives, as this was not fully explored in this study.

References

Alvesson, M., & Sköldberg, K. (2008). *Tolkning och reflektion: vetenskapsfilosofi och kvalitativ metod*. Lund: Studentlitteratur.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining Twenty-First Century Skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st centuary skills*. New York: Springer.

Bjurulf, V. (2008). *Teknikämnets gestaltningar: en studie av lärares arbete med skolämnet teknik*: Karlstad: Estetisk-filosofiska fakulteten, Pedagogiskt arbete, Karlstads universitet.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology, 3*(2), 77-101.

Compton, V. (2013). Developing technological literacy. In J. Hallström & C. Klasander (Eds.), *Ginners teknikdidaktiska handbok: några teser om teknik, skola och samhälle* (pp. 137-155). Norrköping: Centrum för tekniken i skolan (CETIS).

Hallström, J., & Klasander, C. (2016). Visible parts, invisible whole: Swedish technology student teachers' conceptions about technological systems. *International Journal of Technology and Design Education*, 1-19.

Ingelstam, L. (2002). *System: att tänka över samhälle och teknik*. Eskilstuna: Statens energimyndighet.

Ingerman, Å., & Collier-Reed, B. (2011). Technological literacy reconsidered: a model for enactment. *International Journal of Technology & Design Education, 21*(2), 137-148.

Jones, A. (1997). Recent Research in Learning Technological Concepts and Processes. In M. J. Vries & A. Tamir (Eds.), *Shaping Concepts of Technology: From Philosophical Perspective to Mental Images* (pp. 83-96). Dordrecht: Springer Netherlands.

Jones, A., Buntting, C., & de Vries, M. (2013). The developing field of technology education: a review to look forward. *International Journal of Technology & Design Education, 23*(2), 191-212.

Keirl, S. (2006). Ethical technological literacy as democratic curriculum keystone. In J. R. Dakers (Ed.), *Defining technological literacy: towards an epistemological framework* (pp. 81-102). New York: Palgrave Macmillan.

Klasander, C. (2010). *Talet om tekniska system: förväntningar, traditioner och skolverkligheter*. Norrköping: Linköpings universitet.

Koski, M.-I., & de Vries, M. (2013). An exploratory study on how primary pupils approach systems. *International Journal of Technology and Design Education, 23*(4), 835-848.

Kvale, S., & Brinkmann, S. (2014). *Den kvalitativa forskningsintervjun* (3rd edition ed.). Lund: Studentlitteratur.

Lind, M. (2001). *Från system till process: kriterier för processbestämning vid verksamhetsanalys.* (Doctoral Thesis), Linköpings universitet, Linköping.

McCormick, R. (2006). Technology and Knowledge: Contributions from Learning Theories. In J. R. Dakers (Ed.), *Defining technological literacy : towards an epistemological framework* (pp. 31-48). New York: Palgrave Macmillan.

Mitcham, C. (1994). *Thinking through technology: The path between engineering and philosophy*. Chicago: University of Chicago Press.

OECD. (2013). *OECD skills outlook 2013: first results from the survey of adult skills*

Ropohl, G. (1997). Knowledge types in technology. *International Journal of Technology and Design Education, 7*(1-2), 65-72.

Skolverket. (2011a). *Curriculum for the compulsory school system, the pre-school class and the leisure-time centre 2011* Retrieved from http://www.skolverket.se/publikationer?id=2575

Skolverket. (2011b). *Läroplan för grundskolan, förskoleklassen och fritidshemmet 2011*. Stockholm: Skolverket.

Svensson, M. (2011). *Att urskilja tekniska system: didaktiska dimensioner i grundskolan.* (Doctoral Thesis), Linköpings universitet, Norrköping.

Tamir, A., & de Vries, M. (1997). Shaping concepts of technology: from philosophical perspective to mental images. *International Journal of Technology and Design Education, Volume 7, Issue 1-2*, 3-10.

Wells, A. (2013). The importance of design thinking for technological literacy: a phenomenological perspective. *International Journal of Technology & Design Education, 23*(3), 623-636.

Identifying, Developing and Grading 'Soft Skills' in Design and Technology Education: A Methodological Approach

Dr Niall Seery
University of Limerick
niall.seery@ul.ie

Dr Donal Canty
University of Limerick
donal.canty@ul.ie

Adrian O'Connor
University of Limerick
adrian.oconnor@ul.ie

Jeffrey Buckley
University of Limerick
jeffrey.buckley@ul.ie

Andrew Doyle
University of Limerick
andrew.doyle@ul.ie

Abstract

Soft skills (Professional skills) complement hard skills to enhance an individual's relationships, job performance and career prospects. Strategically targeting the development of these skills requires the recognition of key qualities, the capacity to discriminate between qualities (Orsmond, Merry, & Reiling, 2000; Sadler, 2009) and a mechanism that will validly and reliability reward acquisition. Educators and learners must take cognisance of the sophisticated relationships between acquiring content knowledge and professional skills through specific ways of working and thinking.

This research, which is part of a three year longitudinal project funded by the European Commission, frames the initial challenge of untangling *Hard* and *Soft* skills for the purpose of explicit development and assessment.

Understanding the nature of evidence that is suggestive of soft skill acquisition is central to this research. Key design considerations are presented in this paper and outline the potential use of information and communications technology (ICT) to enhance teaching, learning and assessment tailored for the recognition of soft skills.

The paper proposes an assessment architecture that acknowledges the importance of educator, peer, and self-appraisal when adjudicating on subjective and often personal data. The proposal has the capacity to balance, weight, and triangulate the objective and subjective evidence of soft skill acquisition ensuring the validity and reliability of resultant digital accreditation. The work

presented in this paper outlines a conceptual framework for the assessment approach that has been designed for implementation in the initial pilot phase of the GRASS project. On completion of the pilot phase data will be analysed for the validation of the assessment approach which will be presented in future work.

Context

Grading Soft Skills (GRASS Project) is a 3-year longitudinal research project financially supported by the European Union focusing on representing soft skills of learners of various ages and at different levels of education in a quantitative, measurable way, so that these skills can become the subject of formal validation and recognition. The project is being developed with the support of the Lifelong Learning Programme (LLP) of the EU, the flagship European funding programme in the field of education and training. The overall objective of the project is to create mechanisms that enable educators to continuously support, monitor, assess, and acknowledge the development of learners' soft skills by leveraging state-of-the-art ICT tools. The project consortium includes eight project partners from four different European countries. Each partner institution developed specific application cases for the implementation and testing of the assessment approach. The context of the application cases range from lower second level schooling to higher education at University level. A key principle of the project is to create an assessment approach that will accommodate the variables of soft skills, subject discipline and student developmental stage. A key consideration for the research is the impact student experience and maturation will have on the nature of the soft skill presented and the level of attainment. This will be evidenced through the student inputs to the assessment instrument across the range of application cases. An initial pilot phase will investigate the validity and reliability of the assessment approach from the perspectives of specific soft skills, context and student developmental stage. This paper proposes the principle based assessment architecture that supports the grading of soft skills that is applicable to all applications in the pilot phase of the study. Understanding the nature of soft skills is a critical aspect of the assessment architecture design to ensure a valid interpretation of student evidence of capability.

Definition of Soft Skills

It has become critical for educators and educational systems to revise and redefine the knowledge and skills required for living in an evolving world. Many efforts have been made to identify the skills required to successfully navigate this new space, e.g., "21st century skills" (Dede, 2010; Voogt & Roblin, 2012) or "new literacies for the knowledge society" (Mioduser, Nachmias, & Forkosh-Baruch, 2008). Soft skills are closely related to what are described as 21st century skills - a broad set of knowledge, skills, work habits, and personal traits that are considered highly important for success in today's world, especially in modern workplace settings. Soft skills have been defined in different ways, but a common trait of all those different definitions is that they, either explicitly or implicitly, distinguished soft skills from hard or technical skills (Litecky, Arnett, & Prabhakar, 2004). Soft skills have also been defined as a dynamic combination of cognitive and meta-cognitive skills, interpersonal, intellectual and practical skills (Haselberger, Oberhuemer, Perez, Cinque, & Capasso, 2014). They help people to adapt and behave positively so that they can deal effectively with the challenges of their professional and everyday life. The SCANS report (U.S. Department of Labour, 1992) and MODES final report (Haselberger et al., 2014) are two of the most cited and often used lists of soft skills both within employment and educational domains. Haselberger et al. (2014) identifies 22 soft skills and clusters them into three groups: personal, content-reliant/methodological, and social. In the MODES project (Haselberger et al., 2014) each soft skill is defined and also associated with other soft skills, demonstrating that the relationships between individual soft skills and the evidence of soft skill attainment is a complex amalgam of numerous variables.

As a result the GRASS project team initially developed a categorisation that would help focus the learning and assessment activities without atomising the inter-related nature between the soft skills and the subject content being studied. Lorenz (2014) presents the term soft skills as a set of transferable skills that include personal and social behavioural traits and competencies. These socio-emotional skills can be categorised by two distinct perspectives; i) intra-personal skills that support the holistic development of the individual, and ii) inter-personal skills that enable the individual to participate effectively within a society. Aligned with the work of Binkley et al. (2012) this project acknowledges the sophisticated interplay between these dimensions and considers soft skills through the following four categories:

- ***Ways of working (Intra–Personal Development):*** enthusiasm, positive attitude, inquisitive, persistence, self-regulatory, professional
- ***Ways of working with others (Inter–Social Participation):*** collaboration, communication, negotiation, conflict resolution, teamwork, networking, managing divergence, leadership, emotional awareness
- ***Ways of thinking (Intra–Personal Development):*** problem solving, critical thinking, synthesis, evaluation, divergent and lateral thinking, strategic thinking
- ***Ways of thinking with others (Inter–Social Participation):*** creating, refining and negotiating meaning, confidence to be different, differentiation of contributions, exploration, cumulative discourse, disputational judgement

Categorisation is the initial phase of the planning and development of soft skill integration in learning activities. Soft skills are strategically targeted, specific to individual and disciplinary requirements. The study aims to establish a hierarchy and groupings of soft skills for progressive development appropriate to the phases of student cognitive development. This is an important outcome that will be made explicit through the contextual student inputs to the project assessment architecture. The focus of this paper is on the key elements to the assessment architecture that will support the development, capture and evaluation of student capability in the area of soft skills.

Constructive Alignment

Supporting an effective assessment approach requires the underpinning of well-developed and appropriate pedagogical practices. Constructive alignment (Biggs, 1996) is the theoretical underpinning of an outcomes-based curriculum used for devising teaching and learning activities and assessment tasks that directly addresses the nature of learning. Constructive alignment describes the coherence between intended learning outcomes, pedagogical approaches, and assessment strategies in an educational programme (Figure 1). Biggs (1996) suggests that the intended learning outcomes are designed first, teaching and learning activities are designed second, and the assessment regime third. If this sequence is adopted, it is important that activities are designed which enable students to learn and demonstrate achievement at the highest level described by the learning outcomes.
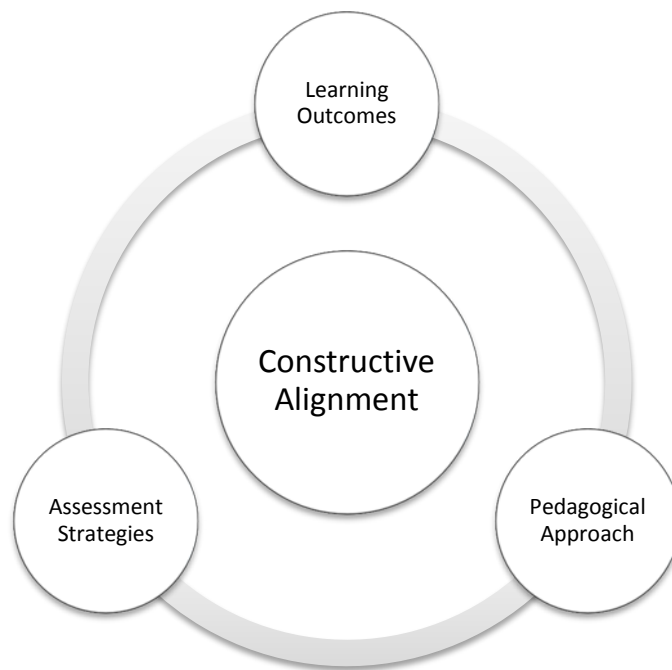
Figure 23: Biggs' Constructive Alignment

This project subscribes to a participative approach to learning, where the dominant pedagogy is drawn from the experiential learning model presented by Kolb (1984). The critical nature of learning task design and pedagogical approach are acknowledged in the overall project, however the focus of this paper is to define an assessment approach that can identify and reward the evidence of qualities associated with soft skills.

Elements of the Assessment Approach

Moore (2004) considers two schools of thought in relation to the teaching and development of soft skills; the *generalists* and the *specifics*. The rising recognition of soft skills in the 1970's was initially approached by generalists' theory and practice. They thought that soft skills were indeed generic, and could therefore be mastered separately from any specific topic/domain and applied to any discipline. By contrast, 'specifics' argue that soft skills cannot be separated from their disciplinary context; they see knowledge as fundamentally situated. There are also *relativists* whose position is in the meridian of the generalist and specific positions. They argue that a generic attribute such as critical thinking needs to be learned contextually, but once learned, can be transferred to another context. This study adopts the relativists position where soft skills and hard skills must be developed concurrently and with the added view that soft skills can only be meaningfully assessed if they have been a central part of the learning activity. This is the first element of the assessment approach.

The second element of the assessment approach establishes the nature of the assessment data for interpretation. The approach taken to the development of soft skills in this research is to support the contextual integrity of this development as an integral part of the acquisition of hard skills. It is widely acknowledged that hard skills are easily differentiated from soft skills. While it is not difficult to identify, develop and reward evidence of hard skills, the evidence of soft skills is somewhat more problematic. Despite clear descriptors of specific soft skills (Griffin, McGaw, & Care, 2012; Litecky et al., 2004) the authentic evidence is not always easily attributable to a particular skill and may in fact represent only partial alignment or suggest multiple skills. The difficulty lies in separating the evidence of specific soft skills from other soft skills, for the purpose

of development and grading. This requires a more qualitative approach, specifically interpretative. The next element to consider is the source of the assessment interpretation.

Although an interpretive approach contrasts with generalizable results, the validity of the measure of soft skills must be considered within the educational transaction and the situational context. In addition, the interpretation of this context and situation can be variable depending on the role of the stakeholder in the educational transaction. It is proposed that the separation of evidence appropriate to the award of a specific skill may only be interpreted validly by the person(s) directly involved in experiencing this evidence as it was created. This is the third element of the assessment approach which identifies the teacher, learner and peer as the sources for judgement on the assessment data. Although it can be argued that the valid interpretation of evidence requires stakeholder involvement, it is considered that interpretations are also variable, especially with respect to maturation, self-efficacy, self-esteem, latent values etc. The capacity of such variables to impact on the validity and reliability of the recognition of soft skills is also a key consideration of the proposed assessment architecture.

Element four of the assessment approach is considered as a key support for the student integration in the assessment process. When embracing a constructivist approach to learning, formative assessment becomes a central issue. As students work within their zone of proximal development (Vygotsky, 1978) their guidance and support from a more skilled person is informed by assessment of their progress. Black and Wiliam (1998) outline the positive influence of formative feedback on student learning. Yorke (2003) details the formal and informal nature of formative assessment and presents the potential of formative assessment in promoting self-regulation in students. This enables students to develop an appreciation of the standards expected of them. Black and Wiliam (1998) report that the effectiveness of formative assessment is dependent on the quality of feedback and the interaction between student and assessor. Black and Wiliam (1998), Orsmond et al. (2000), Sadler (1998, 2009) and Yorke (2003) consider teachers, peers and students themselves as potential contributors to the formative assessment process and outline the importance of strategic planning for the integration of formative assessment into any learning activity. Therefore, the fourth element of the assessment approach is that there must be evidence of teacher and student led formative assessment in the award of the soft skill credential.

Assessment Architecture

The nature of the evidence resulting from the constructivist based approach, supported by active learning methodologies, is personal, diverse and often idiosyncratic. By comparison to evidence of hard skills which tend to be more declarative in nature, soft skill evidence is exposed in the authentic performance of the learner within the learning task, shifting the focus from the 'product' of learning to the actual learning process. The context dependent nature of soft skills requires an assessment approach that offers flexibility in the capture of evidence, clarity in its presentation and coherence in the judgement on evidence of soft skill demonstration and attainment. Aligned with the work of Bevir and Kedar (2008) the GRASS project assessment architecture supports an interpretative paradigm where the evidence is considered within an experience-near orientation that sees the learners' actions as meaningful and progress contingent. This paper proposes four key characteristics of the assessment architecture that supports the grading of soft skills:

- *Capture:* Capture authentic evidence of student performance both reflexive and reflective in a representative form – multi-modal capacity
- *Context:* Accounts for the situational context in which the skill is being demonstrated and presents the learners personal construct of capability by determining what is presented as evidence of learning relative to the task and context

- *Coherence:* Track the multi-modal meta-data produced by students throughout the learning task(s) presenting clear evidence of progression relative to the initial attainment and targeting specific benchmarks
- *Perspective:* Acknowledge the value judgements of stakeholders within the learning task (self, peer and professional) and consider with reference to the experience-near orientation

Authentic Capture

This study aims to create mechanisms and methodologies that will enable educators to develop, support, monitor and assess soft skills through effective pedagogy, integrated assessment and leveraging state of the art ICT tools. This creates the need for a learning management system that supports the non-invasive creation of evidence of learning to be presented for the purpose of assessment. A soft skill credentialing service tool is also required that supports the relevant stakeholder in the learning task to exercise their judgement on the evidence of soft skill attainment. When selecting appropriate ICT tools, digital badges and more specifically Open Badges (OBs) were found as the most viable means of recognising and credentialing soft skills (Jovanovic & Devedzic, 2015). A digital badge is a validated indicator of an accomplishment, skill, quality or interest that can be earned in various learning environments. Their major advantage lies in the traceability and transparency of learning evidence associated with a badge as a digital credential. The approach facilitates the seamless documentation of meta-data that will present the chronology of engagement by the learner throughout the learning task. This will help the assessor gain an insight into the performance of the student to contextually understand the evidence of learning. The badging system can be populated from multiple sources, i.e. learner/peer/teacher, throughout the learning task where the context and discrimination of evidence of learning can be demonstrated. In addition, the reported experiences on the use of OBs in a variety of educational settings indicate that they could serve as a means of; i) motivating learning; ii) charting learning routes; iii) supporting self-reflection and planning and iv) supporting alternative forms of assessment. Accordingly, the project team has decided to rely on the concept and technology of Open Badges coupled with learner-centred, social-constructivist pedagogical approaches, in order to build a viable solution for developing, recognising, assessing, and grading learners' soft skills.

Context and Coherence

Having considered the implication and infrastructural requirements necessary to capture the authentic evidence of the learners' soft skills, the second dimension to the proposed architecture is to explore the inference that can be drawn from the evidence. A key aspect of the architecture is to acknowledge and credit the ongoing development and mastery of the soft skill throughout the learning task. With emphasis on capturing the process of learning, the approach presents the opportunity to track the meta-data accumulated through the digital badging infrastructure as evidence of learners soft skill development emerges. The ongoing visibility of the assessment data through the digital badge award is both helpful for the teacher and learner in tracking progression and identifying the appropriate next step to take. This is important in the development of the student's personal construct of the nature and value of the soft skill being attained. The contextual development and tracking of progression in the learning task presents the opportunity for the learner to identify critical skills to help them effectively navigate the challenges in both their learning and future professional lives.

Perspective

On a systems level the proposed architecture recommends that the decision reached in relation to attainment of a specific soft skills should be an aggregation of the interpretation of the partners in the educational transaction. The significance of the triangulation that respects the learners own self-reflection, the peers experience and evaluation, and the professional's perspective and critique is grounded in the ecological validity of the approach (Figure 2).
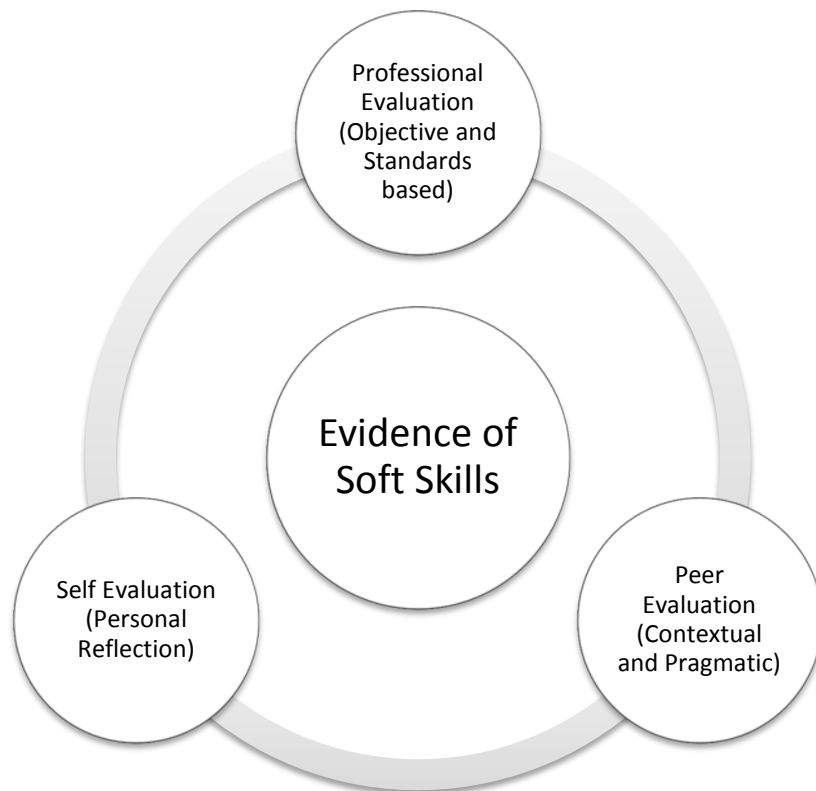
Figure 24: Assessment Architecture

In principle the approach (and technological capacity) supports the dynamic distribution and redistribution of the weighted impact of all three stakeholders' interpretation with respect to the context and situation. For example, it is conceivable that in certain circumstances the peers view of the evidence may outweigh that of the teacher, or the self-evaluation of the learner may be a more reliable interpretation that the peers depending on the nature of the learning task or purpose of the educational intervention.

Discussion

The grading and adjudication of subjective and often tacit soft skill evidence is a complex and intricate process whereby the nature of the evidence mandates a responsive and dynamic approach to the assessment. Understanding the interrelationship between working and thinking independently and with others requires a relativist approach to the grading of these skills. The social-constructivist view of learning is holistic in nature, focusing not only on the construction of knowledge, but also on aspects of attitude, emotions, values and actions (Breck & Kosnik, 2006). This approach encourages the development of relationships between teachers, students and peers, thus creating an environment supportive of personal and academic development. Thus the social-constructivist view of educational practice supports the development of soft skills; however, the problem arises with the tacit and difficult to quantify evidence of learning.

Sadler (2009) strongly advocates that students be inducted into the assessment process to help them make sense of the progress of their learning. This leads to the development of a personal construct of capability by the learner where the learner not only shows understanding of the discipline knowledge/skill but can also discriminate on the quality of performance or attainment. Providing the opportunity to develop this personal construct requires a learning environment that supports the student in their exploration of value and meaning which can be achieved with the

constructivist paradigm (Sadler 2009). Providing the opportunity to exercise their judgement in the award of capability can intrinsically motivate students leading to a more valuable educational experience. Designing an assessment architecture is dependent on the interpretation and judgement of learners and peers must ensure that all learners develop a construct of understanding in relation to the soft skill to ensure validity of the assessment credential.

Exercising the students' self-judgement requires learners to become aware of the sophisticated relationships between ways of working and ways of thinking. This is best achieved through a learning environment that supports students in their exploration of value and meaning (Sadler, 2009). Peer assessment activities are best suited to evaluating student performance in the inter-personal categories of soft skills where they can make judgements based on their authentic experience with others during the learning activity, e.g. ways of working with others and ways of thinking with others.

This approach has potential to help students gain knowledge about themselves. It requires learners to learn how to use knowledge appropriately in a context that is relevant to a given task. For example, having completed some tasks related to the development of collaboration skills students would not only be expected to exhibit good collaborative practice, they would also be expected to identify when it may be beneficial, recognise effective collaborative practices, and identify qualities of collaboration in support of determining varying levels of attainment. The digital badging infrastructure has the capacity to award badges as the evidence emerges over time. The accumulation of badges from the multiple perspectives of self, peer and teacher creates a matrix of evidence that will determine the ultimate award. Determining the appropriate weighting of the individual elements and perspectives is a critical element of this research project.

The assessment framework places the student at the centre of the learning and assessment activity. Learning and assessment is not seen as something that is imposed, but rather as activities that allow them to grow and explore the value of their learning. The real-time capture of authentic evidence for the purposes of evaluation and assessment is a central feature. This has been made possible through the ICT infrastructure and digital badge issuing platform. The dynamic communication between the professional, peer, and self-judgements on quality provides the opportunity for the student voice to be considered in the award. The method employs judgement of quality through skills of appraisal based on a personal construct of capability by the learner, teacher and objective standards. Based on the relativist paradigm, this approach validates judgments based on triangulated data and facilitates the non-uniform rational weighting of judgements in response to context and situation.

The strength of this approach is in the triangulation of judgements to ensure the validity and reliability of the assessment. It is proposed that the outcome of this approach will produce a cumulative score awarding a performance on a descriptive scale. Criteria and levels of attainment for the assessment of qualities of soft skills can then be applied by the awarding body appropriate to the context and needs of their corresponding discipline.

Conclusion

This paper proposes an assessment architecture that focuses on the performative evidence of the learner created in real-time. This evidence is multi-modal and responsive to the needs of the learner or task. Using state of the art ICT tools and services the learners' data can be reviewed and tracked over time to demonstrate progression and competency, with respect to context and situation. Due to the personal and often idiosyncratic nature soft skill evidence, the paper proposes a relativist interpretation of the evidence. Empowering the stakeholders as critical partners in the assessment activity supports the ecological validity of their judgements on the presented evidence. Reliability is strengthened by the triangulation of these judgements.

Exploiting the advances in technology, this approach also proposes the capacity to weight the judgement of stakeholders relative to any given context or situation, usually determined prior to the generation of evidence. Currently, the project is completing the piloting phase where the rubrics for constructive alignment and the assessment architecture are under review. The integration of appropriate ICT tools to support the student and teacher are also being assessed.

References

Bevir, M., & Kedar, A. (2008). Concept Formation in Political Science: An Anti-Naturalist Critique of Qualitative Methodology. *Perspectives on Politics*, *6*(3), 503–517.

Biggs, J. (1996). Enhancing Teaching through Constructive Alignment. *Higher Education*, *32*(3), 347–364.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining 21st Century Skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 17–66). New York: Springer.

Black, P., & Wiliam, D. (1998). Assessment and Classroom Learning. *Assessment in Education*, *5*(1), 7–74.

Breck, C., & Kosnik, C. (2006). *Innovations in Teacher Education: A Social Constructivist Approach*. New York: State University of New York Press.

Dede, C. (2010). Technological Supports for Acquiring 21st Century Skills. In E. Baker, B. McGaw, & P. Peterson (Eds.), *International encyclopedia of education* (3rd ed., pp. 158–166). Oxford, UK: Elsevier.

Griffin, P., McGaw, B., & Care, E. (Eds.). (2012). *Assessment and Teaching of 21st Century Skills*. New York: Springer.

Haselberger, D., Oberhuemer, P., Perez, E., Cinque, M., & Capasso, F. (2014). *Mediating Soft Skills at Higher Education Institutions: Guidelines for the Design of Learning Situations Supporting Soft Skills Achievement*.

Jovanovic, J., & Devedzic, V. (2015). Open Badges: Novel Means to Motivate, Scaffold and Recognize Learning. *Technology, Knowledge and Learning*, *20*(1), 115–122.

Kolb, D. (1984). *Experiential Learning: Experience as The Source of Learning and Development*. New Jersey: Prentice-Hall.

Litecky, C., Arnett, K., & Prabhakar, B. (2004). The Paradox of Soft Skills Versus Technical Skills in IS Hiring. *Journal of Computer Information*, *45*(1), 69–76.

Lorenz, K. (2014). Top 10 Soft Skills for Job Hunters - People Skills and Relationship-Building are Key to Success. Retrieved March 3, 2014, from http://jobs.aol.com/articles/2009/01/26/top-10-soft-skills-for-job-hunters/

Mioduser, D., Nachmias, R., & Forkosh-Baruch, A. (2008). New Literacies for the Knowledge Society. In J. Voogt & G. Knezek (Eds.), *International Handbook of Information Technology in Primary and Secondary Education* (pp. 23–42). New York: Springer.

Moore, T. (2004). The Critical Thinking Debate: How General are General Thinking Skills? *Higher Education Research & Development*, *23*(1), 3–18.

Orsmond, P., Merry, S., & Reiling, K. (2000). The Use of Student Derived Marking Criteria in Peer and Self-assessment. *Assessment & Evaluation in Higher Education*, *25*(1), 23–38.

Sadler, D. R. (1998). Formative Assessment: Revisiting the Territory. *Assessment in Education*, *5*(1), 77–84.

Sadler, D. R. (2009). Transforming Holistic Assessment and Grading into a Vehicle for Complex Learning. In G. Joughin (Ed.), *Assessment, Learning and Judgement in Higher Education* (pp. 45–63). Netherlands: Springer.

U.S. Department of Labour. (1992). *The Secretary's Commission on Achieving Necessary Skills (SCANS)*. USA: Department of Labour.

Voogt, J., & Roblin, N. (2012). A Comparative Analysis of International Frameworks for 21st Century Competences: Implications for National Curriculum Policies. *Journal of Curriculum Studies*, *44*(3), 299–321.

Vygotsky, L. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, Massachusetts: Harvard University Press.

Yorke, M. (2003). Formative Assessment in Higher Education: Moves Towards Theory and the Enhancement of Pedagogic Practice. *Higher Education*, *45*(4), 477–501.

Establishing educational partnerships in order to promotie science learning in the primary school classroom

H. Van Ravenswaaij, Utrecht University, the Netherlands
E. Slot, Utrecht University, the Netherlands
T. van Wessel, Utrecht University, the Netherlands
C. Damhuis, Utrecht University, the Netherlands

e.m.slot@uu.nl

Abstract

Primary school students participating in the educational program 'Engineers in the Classroom' were engaged to interact with and learn from science engineers such as software and design engineers. This stimulates students to develop problem-solving and critical thinking abilities through discovery learning, and pick-up knowledge about the world of scientists and engineers. In the program, teachers, engineers and educational experts collaboratively develop science lessons around a real-world problem central to the engineer's work. Our research question was whether the quality of interaction in the partnerships between teacher, engineer and educational expert was related to satisfaction with teacher-support to translate real-world problems into S&T-lessons in the primary school classroom. Educational partnerships between engineers and teachers are useful for embedding science education in a real and meaningful context, thereby creating distance with traditional science instruction, which is often detached from student's everyday experiences (Aikenhead 2005, Bulte et al. 2006, Duit et al. 2007, Tytler 2007). The collaborative meetings of the partnerships (n = 4) were filmed in order to map the quality of interaction (using Stoll, 2010) and teachers filled out an evaluation survey about their experiences after the program ended. The results indicated that teachers were highly satisfied with the program, particularly with regard to the input of the various stakeholders (engineer, educational expert). Posing a concrete, real-world problem where students were able to generate possible solutions facilitated the teachers in translating an engineering problem to science education in the primary school classroom.

Keywords: science and technology, educational partnerships, community learning

Introduction

Traditional approaches to teaching science and technology (S&T) often fail in stimulating student enrolment, creating a representative image of science or scientists, and creating meaningful contexts outside school for teaching S&T-content (e.g. Aikenhead, 2005). Reforming S&T education into a more constructivist teaching practice (i.e. inquiry-based learning, context-based science education; Nentwig & Waddington, 2005, p. 216) is seen as a solution to the current crisis, as it enables students to learn in meaningful contexts, i.e. as close as possible to a student's daily life (Lave, 1991), and to stimulate their interest in and motivation for S&T content. A 'context' can be defined as the content that addresses student interests, but can also be understood in terms of the broader, societal context (media, peers, parents; Duit, Mikelskis-Seifert, & Wodzinski, 2007). Most importantly, science and technology can be made meaningful by linking it to the outside community (Tytler, 2007).

However, there is a great need for creating sustainable linkages between science education and the outside community of school (Tytler, 2007). Currently, it seems that these linkages are often kept alive by the actions of enthusiastic individuals, although these *educational partnerships* between teachers and professionals from the outside community might be useful for embedding science education in a real and meaningful context, thereby creating distance with traditional science instruction (Aikenhead, 2005; Bulte, Westbroek, De Jong, & Pilot, 2006; Duit et al., 2007; Tytler, 2007).

The current research project evaluates an educational partnership program, 'Engineer in the Classroom', that is developed to support teachers in developing and teaching authentic, context-based, S&T lessons through collaboration with an engineer and an educational expert. We define a partnership as a group of individuals committed to designing instruction, artifacts (e.g., curriculum materials), or science learning environments in a context of collaboration and mutual respect (Linn, Shear, Bell, Slotta, 1999). The partnerships in our program consisted of primary school teachers, technology experts (engineers) and an educational designer. Partnerships were centered around the work of the engineer, e.g. designing medical instruments for hospitals.

Little scientific knowledge exists on the implementation and use of educational partnerships in primary school S&T education, illustrating the usefulness of the current evaluative research. We have decided to regard partnerships from a social capital perspective (Stoll, 2010), since we are *linking* the world outside the school to the curriculum inside school. This process is multi-directional: both teachers and science engineers are willing to contribute to their community. Partnerships can be beneficial for teachers, as some scientific or societal challenges cannot be addressed alone, but also for engineers and scientists in terms of the valorisation of their work (added value to community). Stoll (2010) argues that *dialogue* is the key mechanism by which partnerships connect. The quality of interaction, here defined as the processes and activities oriented towards community learning (Stoll 2010), influences the collaboration of the partnership through four features: (a) supported practice/mutual respect (see also Linn et al., 1991); (b) collaborative inquiry, (c) knowledge integration (Linn et al., 1991), and (d) meta-learning.

Our research question was whether the quality of interaction in the partnerships between teachers, engineer and educational expert was related to satisfaction with teacher-support to translate real-world problems into S&T-lessons in the primary school classroom, in which students could generate possible design solutions. The quality of interaction was addressed by looking at processes and activities between partners (teachers, engineers, educational experts) in the learning community, the teachers' experience with the program and teacher-reported influence of the program on the educational practice.

Methods
Program and Participants
The program 'Engineers in the Classroom' included a kick-off meeting, a collaborative meeting, preparing lessons, lessons by the engineer, a closing educational activity, and an end meeting. One or two primary school teachers, an engineer, and an educational expert collaborated in a partnership. Video data of four partnerships were obtained. At two schools two teachers participated, at the other two schools one teacher each. All teachers were teaching children between 7 and 13 years of age. Each school welcomed a different engineer with a different background. These backgrounds were ICT, ergonomical design, architecture, and medical technology. One teacher of each school completed a questionnaire. All participants spoke fluent Dutch and were able to fully participate in the program.

Procedure, Measures, and Coding
After a kick-off meeting in which almost all participants were present and received information regarding the program, collaborative meetings of each partnership was planned. The main goal of

this meeting was to collaboratively develop lessons around a real-world problem central to the engineer's work. This collaborative meeting (duration 60-120 minutes) was filmed after getting consent from the participants in each partnership. After developing and carrying out the lessons around the real-world problem, teachers from each school ($n = 6$) completed a questionnaire anonymously.

Quality of interaction. The videos of the partnerships were coded on their quality of interaction, that is processes and activities oriented towards community learning. A coding scheme was developed based on the model 'community learning' of Stoll (2010). The interaction between different partners was based on a collective desire to contribute to a larger community. This means that within this program, teachers, engineers and educational experts collaboratively are willing to develop learning in the classroom. The processes and activities in the learning community were described into four categories and include supported practice, knowledge animation, meta-learning with peers, and collaborative enquiry (Stoll, 2010, see Figure 1).

Supported practice refers to the need for one other in a partnership, and is therefore translated to the observable code of sharing information between teacher and engineer(1). Knowledge animation indicates that different partners need to learn from the project, and was therefore coded as whether there was a clear outcome for each partnership (2). Meta-learning with peers refers to the individual needs and learning objectives of the partners, and was translated to (3) practical (i.e., time, space, and means) and (4) content conditions (i.e., clear problem, design and results). The final principle is collaborative enquiry and refers to a common goal; this was therefore coded as whether partners have a common goal (5). At the heart of all of this activity are dialogue and learning conversations.
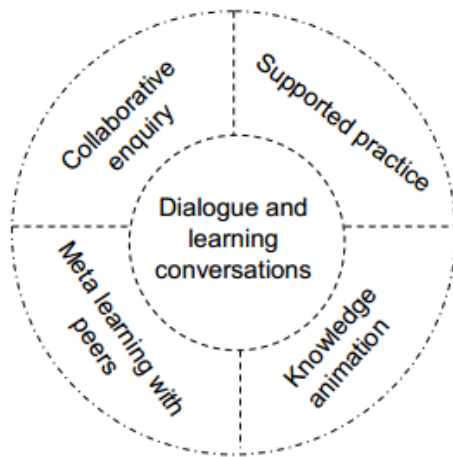
Figure 1. Learning processes and activities in a partnership (Stoll, 2010)

For each discussed theme, the time range/frame and the speaker (i.e., teacher, engineer, or educational expert) was noted as well as exemplifying quotes. These scripts were then coded with the codes based on Stoll (2010), resulting in qualitative data on the interactions within partnerships. Videos were coded until data saturation was attained, which occurred after three videos.

Teacher evaluations. Questionnaires were developed to evaluate teachers' positive and negative experiences with the program. The questionnaire consisted of 16 questions. For each part of the

program participants were asked whether they had included this part in the program and to indicate usefulness. Usefulness was measured on a five point likert-scale ranging from not useful to very useful or from very negative to very positive. Questions regarding performed activities had yes or no answers. For each question, participants were asked to provide open-end positive and negative feedback. Other questions addressed influence of the program on educational practice by evaluating professionalization of the teachers and the reactions of the students. Teachers were asked an overall grade of the program and to give suggestions and comments in the last question. All answers were analysed and summarized in this paper.

Results
Quality of interaction
The analyses of the videos show that almost all learning activities and processes defined by Stoll (2010) were included in the collaborative meeting, but in different degrees. The common goal of the partnership and the practical conditions were only mentioned briefly, as was the clear outcome. In addition, the clear outcome was not explicitly stated in all learning communities. The sharing of information and discussion of content conditions were the most frequently observed aspects during the collaborative meetings.

Common goal. For all collaborative meetings, collaborative enquiry, thus sharing a common goal was observed. The educational experts started all collaborative meetings with stating the common goal of the meeting. For instance:

"We have gathered today to talk about the program and what we will do in the first two educational activities, as well as during the engineer-lesson and follow-up activity."

Sharing information. Much time during the collaborative meeting was spent on sharing information between teachers and engineers. This indicates that there was a need for one another in the learning community consisting of the engineer, teacher(s), and the educational expert. The engineers mainly contributed by providing insight into their work topics and provided suggestions on how these topics can be used in the classroom. For example, an architect in one of the projects looked around the school, and said:

"Not much is needed to transform this school into housing apartments."

Next to providing a solution for the discussed problem, the following engineer also suggests different points of view for a solution:

"You can also look at the solution from different perspectives: nurse, doctor, or patient."
"Students can be provided with different materials to test their design."

The teachers mainly contributed by providing insight in the world of their students and in the primary school curriculum. The main focus of teachers was on how appealing the topic and lessons would be for the students. For instance, teachers commented that:

"It is more appealing for these students when they can see and experience the problem for themselves."

In addition, they discussed in what way the topic and lessons aligned with previous knowledge and the learning goals for primary education. Some examples are:

"The water tower or church can be linked to geography or history."

"We already discussed the water cycle and sewer system. Dykes are furthermore a part of the curriculum, so we can link these lessons to the curriculum."
"Students learned about oxygen in the previous months and they found this quite difficult."

The educational expert was responsible for the design and planning of the program and setting the common goal of the program. During meetings, the educational expert contributed by watching over the agenda, the time and by asking questions on providing information to construct the lessons and to probe the engineer and teachers to generate ideas and think aloud.

Conditions. All partners in a learning community had their individual needs and learning objectives, which were either content-related or practical. These goals and needs largely determined the subject of collaborative meeting.

Content conditions. Regarding the content of the lessons, particularly the educational expert stimulated the others to think aloud and contribute to some topics. First, a problem from the engineer's work environment needed to be chosen, with which the students would work with. After this decision, the educational expert stimulated the participants to think about an engaging activity to start the first lesson with. This needed to be close to the experiences of the students. For example, one learning community thought about:

"There were plans to transform the school into a nursing home, students can think about what that would mean for how the school building is set-up now."

In order to attain alignment between the different lessons, teachers and engineers were advised by the educational expert to have regular contact via email or telephone. The sharing of information about the lessons helps them to shape the different learning activities.
Teachers furthermore wished to enrich their lessons and base it on students' experiences as much as possible. Therefore, they looked for examples or materials in the neighbourhood. This was however not always feasible:

"There are no dykes nearby, but they can use a sandbox and recreate them artificially, that will make it more real."

Practical conditions. Several practical aspects were included: the duration and dates of the lessons, where the lessons would take place, how and where students will present their findings, the size of the groups, and the use of different materials. The following quotes show examples of the use of different materials:

"We can arrange a small sandbox for students to play around with."
"Which different materials are available in the direct environment?"
"There are some churches that are already transformed to apartments, which we could try to visit."

Clear outcome. As all partners were expected to learn from the project, the outcome was discussed in the collaborative meeting. Teachers named the lesson provided by the engineer as an outcome. The educational experts furthermore stimulated the teachers to think about what the students needed to learn. Some teachers mentioned cognitive goals (such as the topic of dykes) and in what way it fitted the curriculum; others mentioned skills such as designing a solution and working with different materials. Not all teachers discussed both cognitive learning goals and skills. However, in one learning community, the two teachers complemented each other:

"Students need to learn about dykes, which function do they have and which types exist. This is quite cognitive, I would like for students to be able to wonder and work from a problem."

Evaluation

The participating teachers rewarded the program with an overall 8.5 (on a scale from 0-10). The kick-off meeting was mainly experienced positively (Table 1), because receiving information and getting acquainted with the partnerships made the program more specific according to the teachers. Being introduced to each other in an early stage was helpful for the collaboration during the collaborative meetings. The different expertise brought together (i.e., teacher, engineer, educational expert) was the most important aspect in this part of the program for multiple teachers (Table 1). After the collaborative meeting, all schools prepared for the lesson of the engineer by organizing lessons with the students beforehand. Furthermore, four of the six schools completed an activity with their students after the lesson given by the engineer. For example, one school expanded their design using a morphological cart, another school went on a field trip, and another school evaluated the program with their students. Teachers perceived the closure meeting as positive (Table 1), because they were given the opportunity to "exchange ideas and listen to other teachers experiences". Although all teachers expressed their enthusiasm, one teacher did not immediately see how the information in the closure meeting could be used, and another teacher found the kick-off and collaborative meeting overlapping regarding its content.

Table #1
Mean Teacher Experiences (Scale 1-5)

Experiences	*n*	Mean
The kick-off meeting was very useful	4	4.0
The collaborative meeting was very useful	6	4.7
The end meeting was very useful	4	4.3
The translation of a real-world problem to the classroom was positive	6	4.0
The alignment of educational activities was good	6	4.3
The educational expert had an added value to the program	5	5.0
The engineer had an added value to the program	6	5.0
The coordination with the engineer was positive	6	4.7
I am able to do this program in the future on my own	6	4.3
I feel stronger as a teacher in teaching technical problems	6	4.5
Students had a positive reaction to the program	6	4.3

The teachers were positive regarding the translation of real-world problems into the classroom (Table 1), mostly because the real-world problems were specific and recognizable for the students. Teachers stated that the educational expert had an added value by providing a clear and structured lesson plan to prepare for the lesson by the engineer. This lesson plan resulted in alignment between the different educational activities. Thus, teachers were very positive regarding the role of the educational expert (Table 1). They were also very positive regarding the role of the engineer, and in a slightly lesser extent, regarding the coordination with the engineer (Table 1). Teachers mentioned two main points, first the enthusiasm of the engineer, and secondly his or her professional expertise. Only one teacher provided an issue, which was that the role of the engineer was not always clear during the program.

On top of the teachers' experiences with the different parts of the program, we evaluated in what way the program influenced their educational practice. All teachers would like to participate in the program again, mainly because they see it as a good way to enrich their (regular) educational activities. One teacher pointed out that the outside community is brought into the school and another teacher liked the fact that students learn more than their textbooks dictate. In addition, teachers also felt fairly competent in running the program by himself or herself, without an educational expert (Table 1). Teachers however think that they would need a lot of time preparing the lessons themselves. On the other hand, they stated that they had gained

experience with the program, and felt more inclined to let their students work with real-life problems again. Finally, teachers reported a positive reaction from their students (Table 1), as the problems were recognizable for the students and they were more engaged in the lessons than usual.

Discussion

Traditional approaches to teaching science and technology (S&T) often fail in student enrolment, creating a representative image of science or scientists, and creating meaningful contexts outside school for teaching S&T-content (e.g. Aikenhead 2005). A major diver for the reform in S&T education is attributed to the practice of science in contemporary settings combined with partnerships between enthusiastic individuals that link school to the outside community (Tytler 2007). In the present study we have evaluated an educational program, 'Engineers in the Classroom', that was developed to support primary school teachers in designing and teaching authentic, context-based science and technology lessons in partnerships with technology- and educational experts. Our research question was whether the quality of interaction in the partnerships was related to satisfaction with teacher-support to translate real-world problems into S&T-lessons in the primary school classroom, in which students could generate possible design solutions. The quality of interaction was addressed by looking at processes and activities between partners (teachers, engineers, educational experts) in the learning community, the teachers' experience with the program and teacher-reported influence of the program on the educational practice.

In general, teachers were quite satisfied with the support given in the partnerships and by the program activities. Given the large amount of time spent on sharing information between teachers and engineers during the collaborative meetings and other parts of the program, we can conclude there was a mutual necessity for one another in obtaining the common goal. The scientists/engineers thereby act as brokers to make the real-world practices available in a school setting (Bronkhorst & Akkerman 2016). Also school content becomes more engaging by representing students' interests in class, for example by personalizing instruction to match students' interests. Collaboration between teacher and engineer may have helped teachers in getting support on how to shift from the role of 'sending information' (instruction) to 'guiding students' (coaching) and an emphasis on the explicit teaching of procedural understanding related to data and evidence, in contrast to reduced emphasis on teaching canonical (science) content.

On request, teachers reported not unanimously positive on running the program once again by themselves. Objections were particularly related to practical issues (e.g. lack preparation time of the lessons) and not so much related to content-related issues or communication with the engineer (e.g. about prerequisite knowledge specific to the engineer's work). Although, the role of the educational expert in the community was evaluated positively in all schools, teachers reported having confidence in running the program again without help of an educational expert. These results raise questions on the compilation and the role of different partners in a learning community for teaching real word based S&T-lessons. For example is the educational expert necessary in repeated execution of the program? Furthermore, the current group of teachers were enthusiastic and volunteered to participate in the program because of personal interest or their role as a science-coordinator in school. To what extent the results of this study may be generalized to the general population of primary school teachers remains to be determined.

In conclusion, there is a value for and a need to develop models of school and community links that are both embedded and sustained. Regarding S&T-education it seems that often such models are initiated and kept alive by the actions of enthusiastic individuals. Despite that, we need such partnerships and programs to be more common in the mainstream delivery of science.

References

Aikenhead, G.S. (2005). Research into STS Science Education. *Educación Química, 16,* 384-397.

Bronkkorst, L.H, Akkerman, S.F. (2016). At the boundary of school: Continuity and discontinuity in learning across contexts. *Edu Rev 190*, DOI: 10.1016/j.edurev.2016.04.001

Bulte, A.M.W., Westbroek, H.B., De Jong, O., Pilot, A. (2006). A Research Approach to Designing Chemistry Education using Authentic Practices as Contexts. *Int. J Sci Educ 28, (9),* 1063–1086

Duit, R., Mikelskis-Seifert, S., Wodzinski, C.T. (2007). *Physics in Context – A program for Improving Physics Instruction in Germany.* Published in Contributions from Science Education Research. Springer Dordrecht, The Netherlands

Linn, M. C., Shear, L., Bell, P., & Slotta, J. D. (1999). Organizing principles for science education partnerships: Case studies of students' learning about 'rats in space'and 'deformed frogs'. *Educational Technology Research and Development, 47(2),* 61-84.

Lave, J. (1991). Situating learning in communities of practice. *Perspectives on socially shared cognition, 2,* 63-82.

Nentwig, P., & Waddington, D. (2005). *Context based learning of science*. Waxmann publishing. New York.

Stoll, L. (2010). *Connecting Learning Communities: Capacity Building for Systemic Change*, Published in Hargreaves, A., Lieberman, A., Fullan, M. and Hopkins, D. Second International Handbook of Educational Change. Springer Dordrecht, The Netherlands

Tytler, R. (2007). *Re-imagining Science Education Engaging students in science for Australia's future*. ACER Press, Camberwell Australia

A Theoretical Model of Technology Education

Mart Soobik;
Estonian Association of Technology Education;
Tallinn, Estonia;
mart@tehnoloogia.ee

In this article, I will use an analysis of literary sources that has allowed me to synthesise a potential theoretical model of technology education (TE). The model consists of five levels, whereas each subsequent level is based on the previous one. The first or base level of the model relies on the philosophy of technology defined by Mitcham (1994) and de Vries (2005). The base level constitutes the level of philosophy of technology, which consists of three important elements: technological values, knowledge and activity. This level supports the next one, i.e. the level of technological literacy and technological competence. Then follows the level of TE curriculum, which consists of TE objectives, content, methods, material-technical basis and in the given case also students' attitude towards the subject. The fourth level contains the fundamentals or components of conducting a TE lesson: creativity; innovation; communication; problem solving; integration; values; cooperation; knowledge and skills; globalisation and cultural background; physical learning environment; digital technology; entrepreneurship. At the fifth level, which is the artefact design or output level, students fulfil a creative task - construct a two- or three-dimensional artefact. Teaching TE using a philosophically orientated pedagogical framework involves open-ended enquiry and dialogue; it requires teachers to listen to and respect pupils' voice (Dakers, 2011).

The objective of the development trends of TE is to shape in pupils a broad vision of the interaction between technology, society and culture in a social context, mainly through solving practical tasks and designing relevant products (a creative process of producing an artefact). The given theoretical model of TE will help to clarify the interaction between several interrelated components of TE in the learning process, where students design an artefact (incl. solve a task). The awareness of these connections will help teachers to better implement the principles emphasised by the TE curriculum.

Introduction

The definition and the role of TE have undergone a considerable change due to global changes in the development of technology in the world as a whole. TE becomes more meaningful and diverse when an open analysis is conducted about the values and lifestyles - the concept of humanity and the world - that the technological way of life is based on, and where the choices will lead (Parikka, Rasinen & Ojala, 2011). The instruction at school must also adopt newer approaches in the field of technology and consider what is reasonable to teach to pupils in the light of the future. TE as a school subject is relatively young and continuously researched, developed and innovated. TE consists of several components and it is important to know what these components are and how they are related to each other. When improving teachers' knowledge basis, it is necessary to focus on the question why we do something and what effect it has. To understand the subject, a comprehensive approach to TE is essential, and therefore I will give a short overview of the theoretical model of TE created by me, and the holistic principles of conducting TE lessons.

Technology education and its theoretical model

I have developed a theoretical framework of TE subjects at school. While developing this model, I
  relied of the materials of the European Union which present the main developments and
  challenges in European education and training that have led to the identification of the new
  priority areas and concrete issues for further work up to 2020 (CEU, 2015). The model (see Figure
  1) consists of five levels, whereas each subsequent level is based on the previous one and the
  movement and development go from more general to more specific or, in other words, towards a
  concrete activity or creating a concrete artefact. The model can be viewed as students' spiral
  development to acquire ability to create/design artefacts in TE lessons.
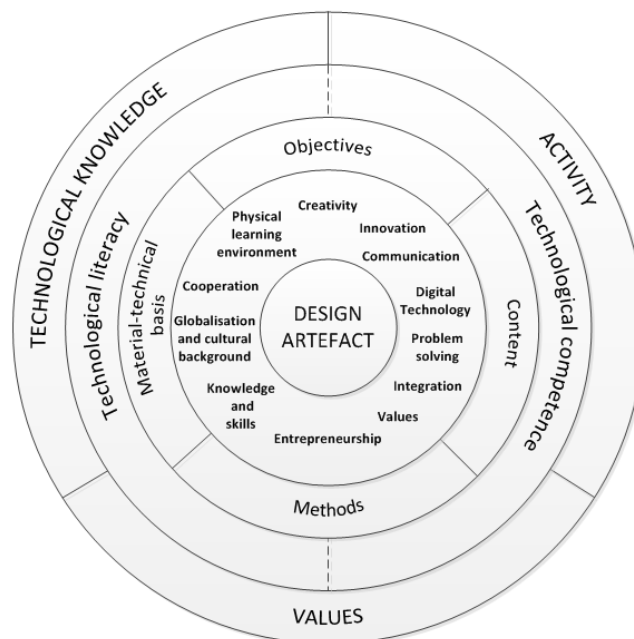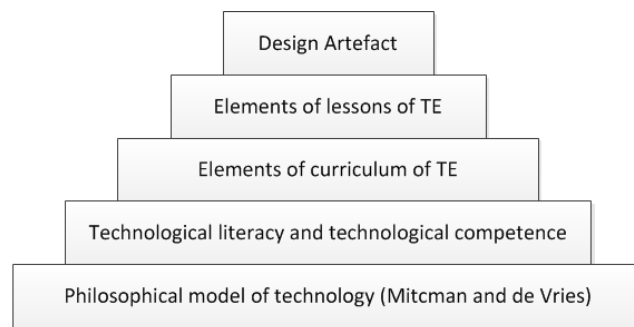
Figure 1. Theoretical model of Technology Education.

The **first or base level** of the model relies on the philosophy of technology defined by Mitcham
  (1994) and de Vries (2005). Mitcham's (1994) comprehensive exploration of philosophy of
  technology issues juxtaposes *engineering philosophy of technology* with *humanities' philosophy of
  technology* and he presents a dialogue between the two (Keirl, 2015). Mitcham's model has been
  further developed by de Vries (2005, 2012) who has given the following names to the four
  approaches to technology: *technology as artefacts; technology as knowledge; technology as
  activities; technology as values*. Keirl (2015) points out that Mitcham (1994) and de Vries (2005)
  are excellent starting points for TE. Adapted by me, the philosophy of technology level consists of
  three important elements: technological knowledge, values and activity.

Technology as knowledge

The 'know how' attributed to technology is what cognitive psychologists call procedural knowledge, which is simply 'know how to do it' knowledge, part of the complexity of it comes in trying to link it to terms such as 'process', 'problem solving', 'strategic thinking' and the like, which in turn requires distinguishing different levels of procedure (McCormick, 1997). McCormick (2002) argued that the linking of conceptual knowledge with procedural knowledge, which he related to 'qualitative knowledge', is central to TE. In TE, the 'technology as knowledge' approach can be used to teach not only how things are, but also about how we would like things to be, pupils must learn to develop ideas about how things can be improved and in what respects (de Vries, 2012).

Technology as values

In the process of designing, children also build their understanding of values and how these are designed into technologies, the values within a design are as much variables as are materials, costs, aesthetics, function and so on (Keirl, 2011). Teaching ethics and values in TE might aim to heighten the moral sensitivity of participants, and secondly, teaching ethics and values in TE might increase the moral knowledge of students (Reiss, 2009). This means that TE teachers must go beyond a limited treatment of the instrumental aspects of technology to consider the value assumptions, cultural influences, ecological impact, work ramifications, economic consequences, and power relationships inherent in technology (Herschbach, 2009).

Technology as activities

At the stage of activation, students should have an opportunity to understand and capabilities through design tasks/learning activities oriented towards sustainable development and global issues. At the stage of the learning experiences, those offered are integrated in day-to-day personal life curricula activities, including projects with communities (Pavlova, 2015). Technological activity is by its nature multi-dimensional, requiring understanding from a variety of points of view, and hence it draws on subjects such as science, mathematics, economics and social studies (McCormick, 1997).

Based on the above, the philosophy of technology level relies on technology-related philosophical aspects, which provide a foundation for understanding technology and TE in human society, what the point of technological development is and how to maintain humanist values while coping with the rapid technological progress. Philosophers of technology emphasise its humanist, ethical and social aspects. It is also important how technology influences the surrounding environment and people, and how people behave in the conditions of technological influence.

The first level supports the next one – **the second level**, i.e. the level of technological literacy (TL) and technological competence (TC). TL gives a very suitable entry to learning about what technology is all about, namely about developing and using objects that integrate human and social needs and wants, hopes and expectations (reflected in the functional nature of the artefact) and the physical resources that we have available in our environment that we adapt to make that environment fit better with our needs (the physical nature) (Frederik, Sonneveld, & de Vries, 2011). Like literacy itself is neither a subject nor a discipline, nor is it static as some kind of body of knowledge, it is naturally integrative and cross curricular, and, like democracy, it can serve, it is fluid and constantly evolving (Keirl, 2011). Willimas (2015) summarises that TE as general education is a study of technology in which students learn about the processes and knowledge of technology in order to develop their TL.

Competences are the dynamic combination of knowledge, beliefs, skills, ability, and values. Autio and Hansen (2002) define TC as an interrelationship between technical abilities in affective, psychomotor, and cognitive areas. According to Autio, TC defines technical abilities as an aggregate of the three above mentioned measurements: emotional, skill, and knowledge engagement (see Figure 2).
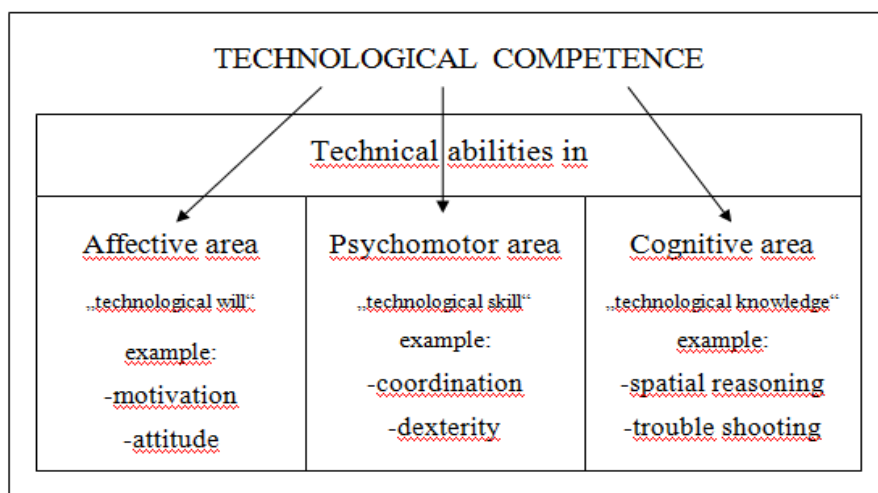
Figure 2. Technological Competence (Autio, 2013).
The affective area contains such terms as "technological will", including, for example, motivation and attitude. The psychomotor area contains "technological skill", including, for example, coordination and dexterity. The cognitive area contains "technological knowledge", including, for example, spatial reasoning and troubleshooting (Autio, 2013).

Next follows the **third level** or TE curriculum level, which consists of TE objectives, content, methods, and material-technical basis. Each country has developed a unique TE curriculum, which instructs teachers in what and how to teach in specific lessons. Nevertheless, it is possible to outline some more general aspects. **Learning objectives emphasise** ethical, humanist and social aspects, how technology influences the surrounding environment and how students should behave. The objectives of TE are to create opportunities for students to learn and develop themselves in the rapidly changing technological world, to acquire technological knowledge and confidence to take risks, to experiment and learn from their experience. It is possible to outline some changes in the **learning content** in Estonia in two different periods of time – in 2004 and 2011. The results reveal that to the traditional activities, i.e. wood and metal work, newer activities have been added (2011), such as robotics and CNC workbenches and the use of the modelling program Solid Edge, Google SketchUp, and Information technology (Soobik, 2015). Today in many schools there are also 3D printers, which students can use to learn to model and print artefacts. Researchers have paid much attention to the study of **teaching methods**, in the centre of which is teachers' role in the teaching of TE, their pedagogical views on learning and teaching strategies. Meriläinen (2006) notes that when considering suitable teaching methods, one must remember that the chosen methods should always be relevant from the point of view of learning objectives, the content taught, the readiness and abilities of the teachers as well as the pupils, the point at which the pupils are located on the continuum of learning and development. **Material-technical learning environment** plays an essential role in putting into practice the innovative trends in TE, a modern and well-functioning learning environment is important in TE, which allows introducing different everyday technical structures in TE. It is very important for schools to have workrooms corresponding to the norms that are equipped with necessary tools and materials.
Based on the views of many authors and priority areas for European cooperation in education and training (CUE, 2015) and my own long experience as a teacher of TE and a researcher, I drew up a holistic model for conducting a TE lesson. I find that from the point of view of TE it is important to look at learning process as a whole, which is created by the elements of the holistic model in interaction. It can be stated that schooling and educational process are increasingly moving towards holistic approach, which unites both learning and teaching and thus also the shaping of a

learners' value judgements. Holistic standpoint stresses the connection between individuals and society, as well as the mutual connection between different meanings (Miller 2000; Poindexter 2003; Hare 2006). The holistic nature of TE lies in the interaction of various factors embodying the teaching. Arising from innovative pursuits of TE, it is sought to employ social context to develop in students a broad vision of interplay between technology, society and culture. **The fourth level** contains the fundamentals or components of conducting a TE lesson: creativity; innovation; communication; problem solving; integration; values; cooperation; knowledge and skills; globalisation and cultural background; physical learning environment; digital technology; entrepreneurship (see Figure 3).
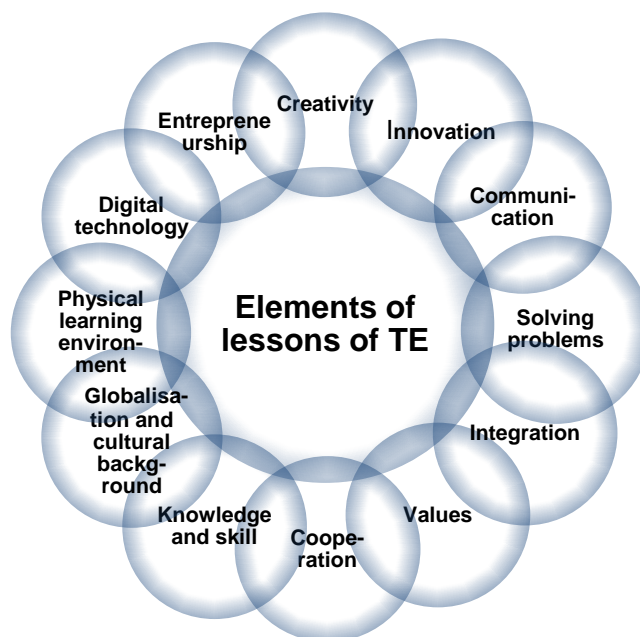
Figure 3. The holistic model of conducting a TE lesson.

This holistic model of conducting a TE lesson helps to clarify the necessity of the presence of several related essential elements in the learning process. The design process presented by the holistic model of TE can also be considered the core of TE, where interrelated elements function newly and freshly, and support students' development. However, subject teachers, their professionalism and meaningful action continue to play the key role in the whole TE learning process.

At **the fifth level**, which is the artefact design or output level, students fulfil a creative task – to create or construct an artefact. During TE lessons, students design an artefact, which plays an important role (de Vires, 2013), and in this learning process need practically all of the elements of the theoretical model of TE. We can start helping pupils to get the basic understanding of artefacts by making them reflect on the physical and functional nature of an artefact (de Vries, 2012). Frederik et al. (2011) emphasise that the conceptualisation of artefacts should be an objective in our teaching about TE. In such an approach students will learn various details about different artefacts that they encounter in daily life. Ginestié (2009) suggests that "studying how and why technological artefacts are developed and used includes an analysis of social interactions and is based on processes related to engineering, the life of products, as well as social sciences." The verb 'to design' means drafting, planning, and creating and design is commonly regarded to be one of the most important and representative activities in technology, and an understanding of design is crucial to TL (Frederik et al., 2011). The mankind does not only have an opportunity to develop and pool their knowledge through the medium of language, they also have a unique

ability to build their verbal knowledge into a physical invention or artefacts. This last level may also include some tasks or activities that are related to students' mental development. They are the outcome of design projects (de Vries, 2007), the outcome of technology, but we often associate them with technology itself (de Vries, 2012).

The levels and their elements presented by the theoretical model, which form a coherent whole, exist in conjunction with each other and support each other, to ensure students' round development through TE. At each level students study and solve various tasks related to concrete student-specific activities of technological world. Some elements of the levels recur while becoming more specific and detailed at each consecutive level.

Conclusion

The developed theoretical model of TE will help to clarify the interaction between several interrelated components of TE in the learning process. An awareness of these connections will help teachers to better implement the principles that are emphasised by the TE curriculum, and involves understanding of the nature of TE. The framework helps teachers to compile TE curriculum containing everything from the philosophy of technology to the creation of an artefact by students.

The theoretical framework is my novel solution, which is why there is no information about other researchers' opinions about this theoretical approach to TE. My theoretical model of TE is not final or unchangeable; it is definitely possible to keep adding new components, which are related to the challenges of the era in TE as well as in the teaching paradigm in general. Attention should be on each learner's needs and abilities with the focus on the 21st century skills, knowledge and attitudes, which are not just subject-centred but cross-curricular – including creativity, social skills, critical thinking, self-regulation, etc. Teachers have to be able to adapt the learning process and teaching materials to the needs of every learner. The future wellbeing of TE depends on the cooperation and readiness of a number of institutions, teachers and opinion leaders to develop and promote the subject in accordance with the established global principles and standpoints inherent in TE.

References

Autio, O. (2013). When talent is not enough: Why technologically talented women are not studying technology. *Journal of Technology Education, 24*(2), *14–30.*

Autio, O., & Hansen, R. (2002). Defining and measuring technical thinking: Students technical abilities in Finnish comprehensive schools. *Journal of Technology Education, 14 (1)*, 5–19.

Dakers, J. R. (2011). Activity theory as a pedagogical framework for the delivery of technology education. In M. Barak & M. Hacker (Eds.) *Fostering human development through engineering and technology education. Reviewing the past twenty years* (pp. 19–34). Rotterdam, The Netherlands: Sense Publishers.

Council of the European Union [CEU] (2015, November 25). *Joint Report of the Council and the Commission on the implementation of the Strategic framework for European cooperation in education and training (ET 2020). New priorities for European cooperation in education and training.* Retrieved from http://data.consilium.europa.eu/doc/document/ST-14440-2015-REV-1/en/pdf

De Vries, M. J. (2005). *Teaching about technology: An introduction to the philosophy of technology for non-philosophers. 27*. Dordrecht, The Netherlands: Springer.

De Vries, M. J. (2007). Philosophcal reflections on the nature of design & technology. In D. Barlex (Ed.), *Design & technology – for the next generation* (pp. 20–33). Whitchurch, England: Cliffe & Company.

De Vries, M. J. (2012). Philosophy of technology. In P. J. Williams (Ed.), *Technology education for teachers* (pp. 15–33). Rotterdam, The Netherlands: Sense Publishers.

De Vries, M. J. (2013). Concept learning in technology education. *Journal of Technical Education (JOTED), 1*(1), S. 147–151.

Hare, J. (2006). Understanding holistic education. *Journal of Research in International Education, 5*(3), *301–322.*

Herschbach, D. R. (2009). *Technology education: Foundations and perspectives.* Orland Park: American Technical Publishers, Inc.

Frederik, I., Sonneveld, W, & de Vries, M. J. (2011). Teaching and learning the nature of technical artifacts. *International Journal of Technology and Design Education, 21*, 277–290. DOI 10.1007/s10798-010-9119-3

Ginestié, J. (2009). Thinking about technology education in France. In M. J. de Vries (Ed.), *International handbook of research and development in technology education* (pp. 31–40). Rotterdam, The Netherlands: Sense Publishers.

Keirl, S. (2011). Primary design and technology thinking in the foundation stage. In C. Benson & J. Lunt (Eds.), *International handbook of primary technology education. Reviewing the past twenty years* (pp. 137–146). Rotterdam, The Netherlands: Sense Publishers.

Keirl, S. (2015). 'Seeing' and 'interpreting' the human-technology phenomenon. In P. J. Williams, A. Jones, & C. Buntting (Eds.), *The future of technology education* (pp*.* 13–34). New York: Springer.

McCormick, R. (1997). Conceptual and procedural knowledge. *International Journal of Technology and Design Education, 17*(1-2), 141–159.

McCormick, R. (2002). Capability lost and found? In G. Owen-Jackson (Ed.), *Teaching design and technology in secondary schools: A reeder* (pp. 92–108). London, England: RoudedgeFalmer.

Meriläinen, M. (2006). *Guidelines on "how to approach teaching and learning?"* Joensuu, Finland: Joensuun yliopiston kirjasto.

Miller, R. (2000). *What is holistic education?* Retrieved January 11, 2009, from http://www.creatinglearningcommunities.org/book/roots/miller5.htm

Mitcham, C. (1994). *Thinking through technology. The path between engineering and philosophy.* Chicago: Chicago University.

Parikka, M., & Rasinen, A. (2009). *Teknologiakasvatus tutkimuskohteena* [Technology education as a research object]. Jyväskylä, Finland: Jyväskylän yliopistopaino.

Parikka, M, Rasinen, A., & Ojala, A. (2011). Technology education. In M. J. de Vries (Ed.), *Positioning technology education in the curriculum* (pp. 133–143). Rotterdam, The Netherlands: Sense Publishers.

Pavlova, M. (2015). Design and Technology education for sustainable futures: In preparation for global citizenship. In K. Stables & S. Keirl (Eds.), *Environment, ethics and culture. Design and Technology Education's Contribution to Sustainable Global Futures* (pp. 87–99). Rotterdam, The Netherlands: Sense Publishers. Poindexter, S. 2003. The case for holistic learning. *Change*, *35*(1), 25–30. Netherlands: Sense Publishers.

Poindexter, S. 2003. The case for holistic learning. *Change*, *35*(1), 25–30.

Reiss, M., J. (2009). Ethical reasoning and action in STSE education. In A. T. Jones & M. J. De Vries (Eds.), *International handbook of research and development in technology education* (pp. 307–318). Rotterdam, The Netherlands: Sense Publishers.

Soobik, M. (2015). *Innovative Trends in Technology Education. Teachers and Students' Assessments of Technology Education in Estonian Basic Schools*. (Doctoral thesis, University of Tallinn, Tallinn, Estonia).

Williams, P. J. (2015). Vocational and general technology education. In P. J. Williams, A. Jones, & C. Buntting (Eds.), *The future of technology education* (pp*.* 201–216). New York: Springer.

Lighting the blue touch paper: Design talk that provokes learners to think more deeply and broadly about their project work.

Kay Stables, Goldsmiths University of London.
Richard Kimbell, Goldsmiths, University of London
Tony Wheeler, New Blue Door
Karim Derrick, Digital Assess

k.stables@gold.ac.uk

Abstract

Design and Technology project-based learning is invariably complex and multi-faceted and part of the challenge for learners lies in managing their way through this complexity. This process is typically mediated through discussions between learners and teachers as 'next steps' are being considered. But there is only one teacher and many learners, so access to teacher guidance can be intermittent and sketchy. This paper will report on a research project that is building an artificial-intelligence design mentor. The ultimate aim is to create a 'sounding board' for the learner when the teacher is not available - an online resource through which (using machine learning) the learner can have a constructive dialogue with an onscreen avatar.

The paper focuses on the development of the dialogic framework of questions that underpins the functioning of the avatar. The research is still ongoing. The framework has been developed through an 'agile' research process, iterating between classroom observation and interventions and analysis and development of both pedagogic and technological aspects.

Through analysis of data thus far, patterns of effective questioning are emerging. In addition, in some instances a question lights a spark in the learner - and through their interaction with the questions not only are they thinking more deeply and broadly but they are actively and speculatively designing through the dialogue. The paper will report on insights from the potential of an on-screen avatar as a 'critical friend' and, possibly more significantly, on ways of structuring dialogue between teachers and learners that is constructive, supportive and genuinely lights the blue touch-paper of creativity.

Key words
Project-based Learning; dialogic pedagogy; design and technology; digital dialogue

Background and Context

Learners undertaking project-based learning in Design and Technology classrooms need frequent access to their teachers, often at times when this is not readily available. The purpose of the research this paper draws from is to establish whether interaction with an on-line avatar is viable and helpful in this context. The results are indicating that such an application is achievable and beneficial to learner's progress and there are two critical elements to the development of the avatar approach. The first of these is technological - to be able to use machine learning to develop an effective web-based artificial intelligence conversational tool.   The second is pedagogical – the tool must support a purposeful dialogue with learners that assists their learning as they undertake their projects. While these two elements are inextricably related, this paper focuses on the second of these and, in particular, the creation and development of a question framework that underpins this pedagogical imperative. Our ambition is to make learning more

444

effective, creating new ways to provide feedback and support for learners through 'digital dialogue'. We asked ourselves *What if…?*

… What if there was an App on each learner's SmartPhone (or tablet, or portable) where they could have a meaningful dialogue with a 'critical friend' avatar when they hit a problem or need reassurance in their decision making?

…What if the avatar gave intelligent and appropriate feedback, linked to what the learner said?

… What if a learner could use this feedback to become 'unstuck, to be nudged forwards so that, when the teacher was available, they would be in a better position to use their one-to-one dialogue with their teacher more effectively?

… What if the system did not 'direct' the learner, but used questioning, acted as a sounding board, enabled learners to reflect on the value of their ideas and speculate on how to develop them?

In the hurly-burly of busy classrooms there is too little opportunity for this personalised talking to take place. Our aim is not to replace teachers but to help optimise time for learning and teaching through individualised project work, supporting diverse groups of learners in ways that nurture creative processes, maintain a sense of ownership, develop reflective and speculative skills and support learners' development as critical thinkers.

The research is a joint venture of educational technologists and D&T educators. Previous collaboration has created ways of learners building web-portfolios using a range of hand-held digital technologies (Kimbell, 2012). These portfolios include voice-files in which learners explain the state of play of their project and ideas for developing it further. These brief statements have a powerful feedback effect on learners' ideas even though they receive no external feedback. The process of putting their thoughts into words clarifies what needs to be done next. These digital portfolios were developed from our much earlier model of assessment for active, project-based learning (Kimbell et. al., 1991) that envisaged a conversational interaction between the ideas that learners have (in their heads) and the expression of those ideas in the external world. Our research builds on this, creating ways to engage in dialogue through a digital interface, enabling the articulation of ideas and challenges, allowing learners to take a critical stance as they identify next steps.

Theories and practices supporting development

Project-based learning is at the pedagogical heart of our digital dialogue system. Project-based learning enables the development of skills such as critical thinking, problem solving, collaboration, communication, leadership and team skills (Dumont et al., 2010). Such skills are now widely recognized as enabling young learners to take responsibility for their own learning, ultimately becoming lifelong learners. However, in practical terms, managing project-based learning and linked opportunities for formative assessment feedback in busy classrooms is difficult.

Our earlier research (Kimbell et al., 1991: Kimbell, 2012) made evident that dialogue lies at the centre of learning processes, including when the conversation is conducted as a private inner process of 'talking to ones-self'. The importance of dialogue in teaching and learning is well established - the recognition of this dating back as far as Socrates. Through questioning and discussing ideas learners are helped to formulate new understandings that can be transformative in the learner's development.

Considerable amounts of research have focused on the value of dialogue in learning. Mercer (2002), for example, building on Vygotsky (1978) highlights the importance of language as a tool for

thinking and the value of dialogic processes in classrooms. Matusov and Miyazaki (2014) make a clear distinction between dialogic processes, focusing on dialogic pedagogy and differentiating what they describe as instrumental dialogic pedagogy, such as dialogue that is aimed at "curricular endpoints preset by the teacher or state" (p?) as opposed to ontological dialogic pedagogy that emphasises meaning making. Hamilton (2007), researching explicitly in the field of D&T stresses the importance of the using hypothetical and powerful questions and speculative language.

The importance of well structured, positive interactions through which a learner's work is understood and critiqued is a central pedagogic practice in higher levels of design education, often in the context of one-to-one conversations between a tutor and a student. (Goldschmidt et al., 2010). Such conversations have been referred to as the "bread and butter of design learning: the main pedagogic object of interaction" (Ward, 2013). There is also recognition that the way in which such dialogue is managed is significant in the impact it has. Exploratory research seeking to understand approaches to such conversations with secondary aged learners showed that teachers being aware of the different roles they needed to play - managing the discussion, mentoring or coaching the learner, making judgements, allowed the teacher to be more confident and learners to develop a greater sense of autonomy (Lawler et al., 2012). In our own previous research (Kimbell, Stables & Green, 2006) analysis of interactions between teachers and learners at different stages of mainstream schooling (from age 5 to age 16) showed stark differences between phases of education, with supportive interactions outweighing teacher 'direction' in primary schools, and the reverse in secondary schools, especially with 11-14 year olds. Two important dimensions emerged from this. First, learners in primary classrooms were more likely to take responsibility for managing their projects than 11-14 year olds in secondary classrooms. Second, primary learners were more likely to spend time in dialogue with each other, while 11-14 year olds were more likely to spend time in queues waiting to speak to their teacher. The pedagogic importance of such dialogue cannot be overstated. The ways in which we humans formulate concepts and understandings through exploring and discussing with another person is fundamental. It allows us to speculate, reflect, critique and question in ways that we can test out and share understandings and use these as the basis for how future actions are mediated and decided upon.

But all of the above research has involved dialogue between human beings. Finding ways of creating meaningful dialogue with some form of 'surrogate' teacher online, has focused us on the nature and impact of questioning – and creating a framework for questioning that simulates that which might be had between a learner and teacher in a design project.

Methodology

The funding for the research has been staged. First phase funding was for 'proof of concept', the second for the realisation of a developed prototype. In both phases we have adopted an 'agile' research process, built iterations of classroom observation and interventions with analysis and development of both the pedagogic and technological aspects.

In phase 1 initial observations focused on dialogue between teachers and older learners (16-18 year olds) working on examination D&T projects. At this stage we worked with 'expert' teachers, experienced in facilitating design activity 8 trial schools (12 teachers, 100 learners). We started by observing, recording, transcribing and analysing what, in effect, were project tutorials to understand existing patterns of conversation. In addition, we interviewed teachers and learners to gather feedback on the process. We progressively teased out an initial framework of open questions starting with 'Tell me about your project'. The conversation then moved into one three strands: 'What is special/exciting about your ideas so far?' 'Who are you designing for?' or 'What

will your ideas need to do to be successful?'. From this framework we produced a common script of branching procedural questions. Following validatory discussions with the teachers, we took this framework to schools, this time with researchers asking questions. At this stage a key emerging issue was with whom the conversation should be undertaken. The learner on one side – but who on the other? We explored – and eventually resolved - a physical avatar in the form of a yellow rubber duck. Originating as an approach in computer programming (Hunt & Thomas, 1999) the rubber duck provides a non-threatening sounding board that we explored through a third round of testing as a real object for learners to interact with in advance of a screen-based avatar. In the final round of trials, the duck moved on-screen, allowing us to field test the interface using a single strand of questioning and machine learning. Learners responded positively –

"I felt it was useful coz it made me realise that there's more things that I do actually need to improve in the product... When I'm just doing it on the computer I'm kind of being safe about it whereas the duck asked me questions that I kind of needed to answer for my product to be better in the end".
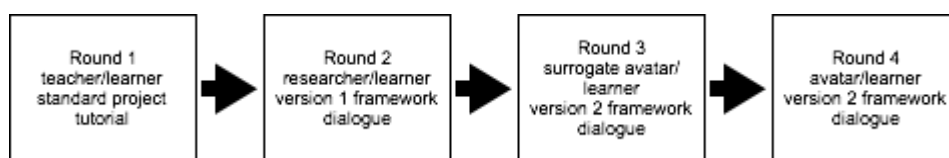
Figure 1. the sequence of fieldwork interventions in phase 1

Phase 1 demonstrated that the 'concept' was feasible. While the initial online trial had a restricted set of questions it gave us (and the funders) confidence that a system could be developed.

Building an extended framework

Phase 2, which is currently underway, began with us re-visiting and developing a fuller version of the framework. In phase1 it was evident that assessment criteria for upcoming examinations were influencing interactions. There was a noticeable contrast between 'open' tutorials where the criteria were implicit and than those that were 'closed' and specifically driven by mark schemes, the first exemplifying 'ontological dialogic pedagogy, while the second were instrumental (Matusov and Miyazaki, 2014).

In the more open conversations teachers took time to explore learners' ideas and intentions, initially asking questions to draw out their learners' intentions and then framing more questions to progressively nudge and extend their ideas.

Teacher: How are you going to keep it shut?
Student: I don't know what they're called. I need to research that but like you have like a thing coming out there and then one metal thing that's like indented there and it like clips in. I don't know what they're called. We have them at home for cupboards. So I'll ask my mum. And they're like really good coz...
Teacher: Rather than ask your mum..?
Student: I'll go into that and research...
Teacher: Or..?
Student: Or the text book?
Teacher: Or go to a shop?

Student:		Oh OK. I'll go to a shop (laughs)

Teachers more concerned with external assessment tended to frame closed statements, directing next steps, rather than drawing these from learners.

Teacher:		Just be careful with not using enough different types of media to explain what's going on, so on each of those pages you need to make sure you've got some modelling, which I know you have and you're struggling with...
Student:		Yeah.
Teacher:		But you need to make it a priority now.
Student:		Yeah. Sure.
Teacher:		And then also you need to go back to your research section. You have more visual bits of media that you could put on there. So for example like the pie chart from there…

This alerted us to identify the nature of the interaction and the response this prompted. Was it a question or a direction? Did it encourage explanation, valuing, developing? What was the design intention and was it the teacher or the learner who was having or valuing the ideas? Was the learner concerned client needs, how their idea would work technically, what the aesthetic considerations might be? Coding interactions helped us isolate these different foci, but created a complex framework. We went back to research on tutorials discussed earlier (Goldschmidt et al.,2010; Lawler et al., 2012; Ward, 2013) and whilst each set used different terminology, there were common threads that we grouped into three overarching categories.

- *mind-reading* questions such as "What are you designing?" getting to grips with what the learner is trying to do
- *managing* questions such as "How are you going to make it work?" "What will it look like?" to reveal a learner's grip on resolving and realising their project.
- *mentoring* questions such as "How do you think its going?" "What needs more attention?" helping learners make independent judgments and decide what they might do next.

We re-coded the sample interview exchanges against these and from this were able to construct a simple branching framework which located the questions extracted from the transcripts. Cross referencing this basic framework against prompts and corresponding student responses we extended each of these 3 strands into a series of more detailed questions.   Borrowing from our previous assessment research (Kimbell et al., 2004) we introduced a valuing question based on a scale using everyday terms from "Wow!" (risky exciting, never seen this before) to "Yawn!" (routine, boring, formulaic) and created three dimensions to the valuing

- ideas scale from "Wow" to "Yawn"
- designing for users scale from "Life-changing" to "Landfill"
- ease of construction scale from "Easy-Peasy" to "Un-makeable"

When used to prompt learners to self-evaluate, they provided a powerful stem for reflection and action.

"I definitely thought it has been useful... you know actually speaking about it out loud has made me kind of realise what I need (laughs)... how much I need to do for the deadline... It's also kind of made me have, you know a few more ideas on how I can develop my product and how it can be more "wow" instead of "landfill".

Early in Phase 2 it became apparent that the most challenging and neglected design aspect for learners was focusing on who their design was aimed at – they were much happier talking about what they would make and how they would make it. Again referring back to earlier research, we

introduced three branches to the questioning framework – one focused on the user, one on technical/making issues and one focusing on aesthetic requirements. These followed the mind reading 'Tell me about your project – what are you designing" question and the branching responded to their answer – the duck took them down the branch they hadn't mentioned in their answer. So, if no user was mentioned, the duck immediately started asking questions about their user. We also become aware of the need to differentiate questions depending on whether they were in early middle or late stages of their project.

Blue touchpaper questions and responses

In previous research we had experimented with ways of disrupting learners' ideas to get them to shift towards more creative thinking, to take risks. In a previous project we had asked learners, half way through a design task to note down their best idea so far, their wackiest idea, biggest problem and next steps. Wackiest idea always demonstrated creative thinking. In the current research we had a hunch that, if we could find the right 'left field' questions and the right way to ask them, we could stop learners in their tracks, get them to think differently. While elusive, we saw these as questions that could spark imagination, light a blue touchpaper. Our initial set of questions included questions such as

how would you change your product if
- you had to make 1000?
- It had to be composted after use?
- there was no gravity?
- It had to last a lifetime?
- It had to flatpack?
- It needed to work under water?

We saw potential in the questions, but working out how and when the duck would ask them was challenging. In the meantime, the revised and extended framework was tested through face to face discussion with a researcher and 200+ learners aged 11-18 in 10 schools. In a small number of cases, there were surprising interactions where it was clear that the discussion was provoking speculative development of ideas by a learner – what we came to describe as 'blue touchpaper' responses. The following example illustrates one such conversation with a learner who was designing a game for a child.

Interviewer: You've said why they need your product. How could you change your ideas to work for different people?
Pupil ….So .... I think ... coz I'm aiming it for younger children right now it's a lot less sort of ... like intimate ... and more just having fun in, like the actual aesthetics. But if I was using it for say somebody who's been in a car crash and is trying to get their hand eye coordination back ... I'd probably make it a lot more difficult ... and like make it so that they could change the settings of the game so it could be easy, difficult... just so that if they're progressing with their hand eye coordination it could be easier or harder.

Seeking to understand what might have provoked blue touchpaper responses, we analysed discussions to identify the nature of questions asked and responses given. The results from this were stark – considerable numbers of responses were descriptive in nature. Much rarer were responses that were developmental, either being speculative about how ideas might develop, or critiquing what they had done.

So, we returned to consider the nature of the language of the questions we were asking and, in particular, the extent to which the language of the questions was speculative.

Questions often begin with a 'stem' of "What", "Who", "Why" or "How". What follows from the stem then determines the nature of the question. For example, "What is …" provokes a descriptive response – the question is asking about something that already **is** in existence – "What is the material you are using?". Shifting the question to "What if …" encourages speculation – "What if the material you are using isn't strong enough, too expensive, too damaging to the environment" etc etc.   This use of speculative language was identified by Hamilton (2007) as significant in creating effective dialogue in learning contexts. Our suspicion was that part of the reason that so may of the learners' responses, at this point in our research, were descriptive was because they had been asked a question that prompted a descriptive response. Further analysis gave a clearer picture of this.

Figure 2 shows examples of mind reading questions from three points of development of the framework, the initial framework from early in Phase 1, a developed version, close to the start of Phase 2 and the latest version, just before the framework was moved on-line. Identifying whether questions use descriptive or speculative language begins to paint a picture of the type of prompts the learners are responding to, with descriptive language marked in red, speculative language marked in blue.

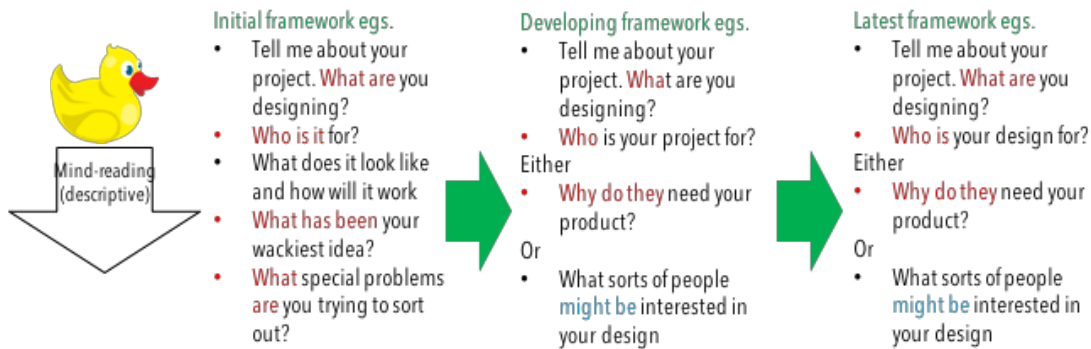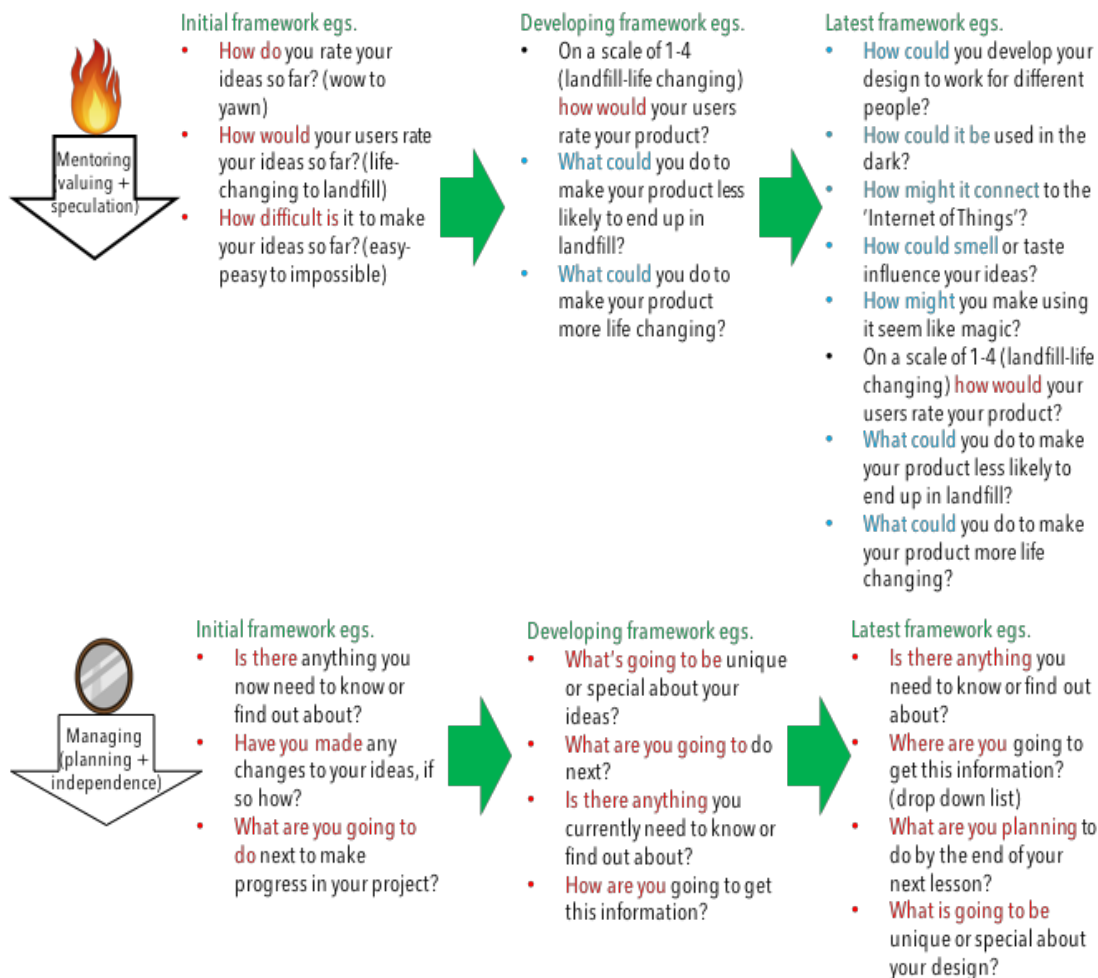Figure 2 Examples of the development of 'mind reading' questions

Following this same approach for the other two elements of the framework builds a fuller picture, illustrating how speculative language has been used increasingly as we have become aware of the need to move learners beyond *describing* what **is** to a position where they *critique* their existing ideas and *speculate* on how **they could develop** them.

Mentoring (valuing + speculation)

Initial framework egs.
- How do you rate your ideas so far? (wow to yawn)
- How would your users rate your ideas so far? (life-changing to landfill)
- How difficult is it to make your ideas so far? (easy-peasy to impossible)

Developing framework egs.
- On a scale of 1-4 (landfill-life changing) how would your users rate your product?
- What could you do to make your product less likely to end up in landfill?
- What could you do to make your product more life changing?

Latest framework egs.
- How could you develop your design to work for different people?
- How could it be used in the dark?
- How might it connect to the 'Internet of Things'?
- How could smell or taste influence your ideas?
- How might you make using it seem like magic?
- On a scale of 1-4 (landfill-life changing) how would your users rate your product?
- What could you do to make your product less likely to end up in landfill?
- What could you do to make your product more life changing?

Managing (planning + independence)

Initial framework egs.
- Is there anything you now need to know or find out about?
- Have you made any changes to your ideas, if so how?
- What are you going to do next to make progress in your project?

Developing framework egs.
- What's going to be unique or special about your ideas?
- What are you going to do next?
- Is there anything you currently need to know or find out about?
- How are you going to get this information?

Latest framework egs.
- Is there anything you need to know or find out about?
- Where are you going to get this information? (drop down list)
- What are you planning to do by the end of your next lesson?
- What is going to be unique or special about your design?

An interesting aspect of this analysis is not *that* we have increasingly used speculative language, but *where* we have used it. Looking at the latest version of the framework it can be seen that description is important at the start – the duck needs a descriptive account of the learner's project in order to draw a relevant next question from the database. It is also useful for the learner – a 'stock take' of where they are. But quite quickly learners are drawn into speculate framing of questions – not "how does …" or "how would …", but "how could …" and "how might …". This encouragement for them to speculate leads to a descriptive "how would your users rate your product" and then back to speculation as they think of ways their product could avoid landfill, be more life changing.

Interestingly, when we applied the analysis to the development of the 'left field' questions, we saw a similar picture in the shift of language, as is shown in Figure 3

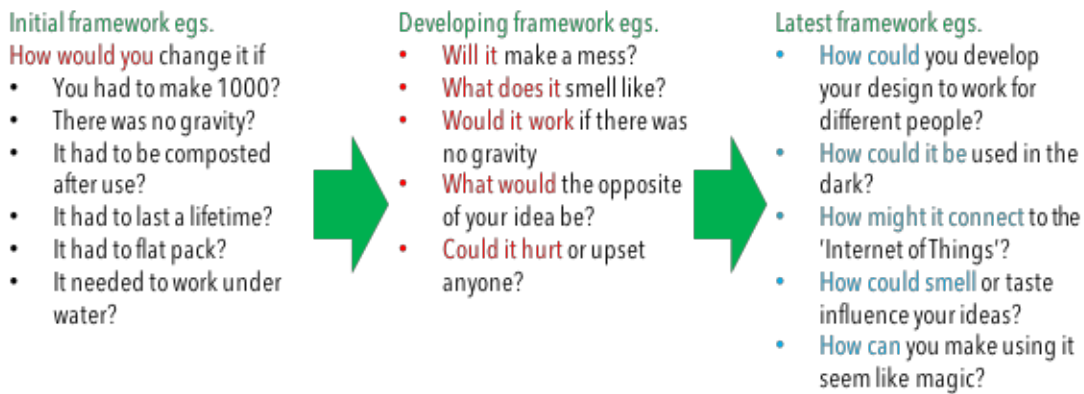| Initial framework egs. How would you change it if	Developing framework egs.	Latest framework egs.
• You had to make 1000? • There was no gravity? • It had to be composted after use? • It had to last a lifetime? • It had to flat pack? • It needed to work under water?	• Will it make a mess? • What does it smell like? • Would it work if there was no gravity • What would the opposite of your idea be? • Could it hurt or upset anyone?	• How could you develop your design to work for different people? • How could it be used in the dark? • How might it connect to the 'Internet of Things'? • How could smell or taste influence your ideas? • How can you make using it seem like magic?

Figure 3 The shift towards speculative language in 'left field' questions.

The research is still underway – as we write the first major trial of the new framework with an on screen avatar has just begun. We don't know what effect the shift in language will have, nor do we know how effective the 'left field blue touchpaper' questions will prove to be. What we do know is that learners are happy to have a conversation with an onscreen avatar, and in the latest trial are asking for access to have repeat dialogues! We are confident that the technical system will work. And importantly, we have a great deal more insight into how and when to use speculative language in creating interactions with learners, on or off screen.

References

Dumont, H., Istance, D., & Benavides, F. (2010). *The nature of learning: using research to inspire learning*: OECD Publishing.

Goldschmidt, G., Hochman, H., & Dafni, I. (2010). The design studio "crit": Teacher–student communication. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 24*, 285-302.

Hamilton, W. (2007). *Constructing classroom learning environments that are interactive and authentic and aim for learner empowerment*. Paper presented at the The Design and Technology Association International Conference 2007, University of Wolverhampton, Telford Campus.

Hunt, A., & Thomas, D. (1999). *The pragmatic programmer: From journeyman to master*. Stoughton, Massachusetts: Addison Wesley Longman inc.

Kimbell. (2012). Evolving project e-scape for national assessment. *International Journal of Technology and Design Education, 22*(2), 135-155.

Kimbell, R., Miller, S., Bain, J., Wright, R., Wheeler, T., & Stables, K. (2004). *Assessing Design Innovation: a research and development project for the Department for Education & Skills (DfES) and the Qualifications and Curriculum Authority (QCA*. Retrieved from London:

Kimbell, R., Stables, K., & Green, R. (1996). *Understanding practice in design and technology*. Buckingham UK: Open University Press.

Kimbell, R., Stables, K., Wheeler, T., Wozniak, A., & Kelly, A. V. (1991). *The assessment of performance in design and technology*. London: SEAC / HMSO.

Lawler, T., McTaminay, A., de Brett, S., & Lord, A. (2012). *Design mentoring and designerly attitudes*. Paper presented at the Technology Education in the 21st Century: The PATT 26 Conference, Stockholm.

Matusov, E., & Miyazaki, K. (2014). Dialogue on dialogic pedagogy. *Dialogic Pedagogy: An International Online Journal, 2*, 1-47.

Mercer, N. (2002). Developing dialogues. In G. Wells & G. Claxton (Eds.), *Learning for life in the 21st Century: Sociocultural perspectives on the future of education* (pp. 141-153). Oxford: Blackwell.

Vygotsky, L. S. (1978). *Mind in society; the development of higher psychological processes*. Cambridge, Mass: Harvard University Press.

Ward, M. (2013). Design tutorials: the basics*2015*. Retrieved from
http://sb129.com/2013/11/08/design-tutorials-the-basics/ website:

Designing a module for authentic learning in upper secondary technology education

Joachim Svärd
Linköping University
Norrköping, Sweden,
joachim.svard@liu.se

Konrad Schönborn
Linköping University
Norrköping, Sweden
konrad.schonborn@liu.se

Jonas Hallström
Linköping University
Norrköping, Sweden,
jonas.hallstrom@liu.se

Abstract

According to the Swedish upper secondary curriculum (Skolverket, n.d.), the subject of technology should allow students to develop entrepreneurial skills, defined as supporting curiosity, confidence, creativity and courage, resulting in the ability to act, in innovation and problem solving. Beghetto and Kaufman's (2014) view of creative learning includes, "having students identify a need and work collaboratively with each other and outside experts to develop a creative solution for that need will help them creatively and meaningfully use what they have learned in the classroom" (p. 65). This kind of learning is related to the notion of authentic learning. Herrington and Parker (2013) define authenticity by nine key elements, namely, authentic context, authentic task, presence of expert performances, multiple perspectives, collaboration, reflection, articulation, metacognitive support and authentic assessment. The aim of this study is to map key elements of authentic learning onto the development of a five-week innovation project for implementation in a Swedish upper secondary school context. Following design and a first round of module implementation, a subsequent pilot study has deployed written questionnaire and semi-structured interview methods to investigate students' opinions of the authenticity of the module and its outcomes. The paper also presents some early findings from this pilot study.

Keywords: upper secondary education, technology education, authenticity, module, Sweden, pilot study

Introduction

Designing authentic scenarios is a key challenge for any teacher, as risk taking, questioning, creating and imagining, cannot flourish under stressful conditions (Ciolan & Ciolan, 2014). Beghetto and Kaufman (2014) add that, "teachers should view themselves and their teaching as a creative act. They will then be in a better position to model, encourage, and support their students' novel ideas, sensible risk-taking, curiosity, and meaningful self-expression" (p. 65). Weimer (2013) has introduced Learner-Centered Teaching as a means to foster such an approach. This method requires teachers to transfer some of the teaching control to the students themselves, as well as encourage collaboration and reflective skills.

Authentic learning is described extensively in the literature, but with a major caveat; there is no clear-cut and operationalised definition for what elements actually constitute *authentic learning* per se. For example, the idea can comprise multiple aspects depending on whether you are a student or a teacher, on whether problems need to be perceived as authentic by the pupils themselves or with regard to technological praxis, as well as on the meaning of the term in relation to technology programmes (Turnbull, 2002). Furthermore, Turnbull (2002) has also asserted that an underlying challenge is having the idea of authenticity implicit in the curriculum in a manner that is both meaningful *and* useful to students. According to Hennessy and Murphy (1999), successful authentic activities that are associated with engaging and encouraging learning are those that are personally meaningful to the student, and purposeful from a societal point of view. Such an approach often takes the form of getting pupils to solve problems seen as real dilemmas where the pupils also become emotionally engaged in finding a solution to the problem. In a broad sense, most people concur with ideas such as authentic learning being about real-world problems dealt with within ill-defined borders in order to promote "21st Century Skills" such as creativity, critical thinking and problem solving capability (Brown, Collins & Duguid, 1989; Collins, Brown & Newman, 1989; Herrington, Reeves & Oliver, 2010; Nicholl, Flutter, Hosking & Clarkson, 2013; Reeves, 2002).

In terms of the connection of 21st-century skills with ideas of authentic learning, Rotherham and Willingham (2010) lucidly suggest that, "advocates of 21st-century skills favour student-centered methods–for example, problem-based learning and project-based learning–that allow students to collaborate, work on authentic problems and engage with the community" (p. 19). We also find such aspects of direct relevance to the idea of authentic learning in teaching. The aim of this paper is to map key elements of authentic learning onto the development of a five-week innovation project for implementation in a Swedish upper secondary school context. One advantage for students familiar with authentic learning is that due to the complexity of the tasks, they develop an ability to validate sources of information, patience, strategies for finding relevant patterns in unfamiliar contexts, and flexibility in working across disciplinary and cultural borders to generate innovative solutions (Lombardi, 2007). In support of this view, Brown *et al.* (1989) suggest that, "… in order to learn these subjects (and not just to learn about them) students need much more than abstract concepts and self-contained examples. They need to be exposed to the use of a domain's conceptual tools in authentic activities – to teachers acting as practitioners and using these tools in wrestling with problems of the world" (Brown *et al.*, 1989, p. 34).

Reeves, Herrington and Oliver (2002) characterise authentic activities as having real-world relevance, being ill-defined, complex and requiring a longer time to solve, providing opportunities for students to examine the tasks from different perspectives, providing collaborative and reflective opportunities, integrating different subject areas, including integrated assessment, ending in a polished product not part of a series of prepared steps, and, finally, being open to different answers or solutions. In a major study of Chicago schools, Newmann, Bryk and Nagoka (2001) found a significant difference in performance between students exposed to authentic classroom tasks and those who were taught in a traditional manner. No matter what group or background they analysed, the students always benefitted from being taught authentically in school.

Authentic tasks in technology

Typical for technology education is the focus on the process of design and development rather than merely on the learning of knowledge. Solving real-world problems enhances this ability. However, assessment of students' ability in designing and developing solutions is much more complex than the mere assessment of their knowledge and skills. The development of teaching activities to meet the demands of ever more complex daily life situations for students, involving new materials, technologies and systems, can be very demanding (Fox-Turnbull, 2006; Kimbell, 1997; Snape & Fox-Turnbull, 2013). In this regard, de Vries, Hacker and Burghardt (2010) assert that:

Teaching about technology and engineering is a challenge, given the impressive speed of technological development. If the goal is to educate for the future instead of the present or past, rapid changes in the technological domain make this work challenging (de Vries *et al*., 2010, p. 15).

It is within this context we set out to develop a new teaching approach in Swedish technology education. All students in the Technology program at upper secondary level in Sweden have to attend the course *Teknik 1* (Technology 1), which makes it a good candidate course to study any potential intervention. Since we are interested in studying the effects of an authentic learning activity, a major product- or service development project will be included in the course, so that students can work authentically, in line with Beghetto and Kaufman's earlier assertion.

An Innovation Project (IP), where the students plan their own work, adopt their acquired skills and knowledge and test their abilities in an authentic real-life project, could be a task that could potentially result in the desired effect of nurturing keen and eager students (cf. Nicholl *et al*., 2013). The IP should last the entire first year at upper secondary school, but in the form of various smaller components and one major component of about 5 weeks. The students spend 26 – 40 hours of the total allocated teaching time on the project (up to a third of the entire course). The available time spent on the innovation project also depends on the possibility of cooperating with other STEM subjects and language subjects such as Swedish and English.

According to Herrington & Parker (2013), the key elements of authenticity are: Authentic context, Authentic task, Presence of expert performances, Multiple perspectives, Collaboration, Reflection, Articulation, Metacognitive support and Authentic assessment.
Following the mapping of these key elements onto development of the IP module, a subsequent study will be conducted to investigate the influence of the module in the teaching of technology, as well as other subjects, in upper secondary schools.

Methodological perspectives

In a series of videos available on the internet, Herrington demonstrates examples of questions one could ask as to whether the conditions in each of the elements of authenticity are met. We are using these questions as a source of inspiration when designing questionnaires to be filled in by the students after the pilot study (http://authenticlearning.info /AuthenticLearning/Home.html). Since Ciolan and Ciolan (2014) have shown great discrepancies between the teacher's point of view and the student's, it could also be interesting to compare the view of the group with one of the teachers, by posing questions such as, Does the engagement during the IP module affect the outcome of the project? Do the students feel a higher degree of satisfaction with the outcome? Other interesting aspects to measure are how the entire course is perceived by posing questions such as, Did the course increase motivation among the students in other subjects such as Science,

Mathematics, Swedish or English? Is there a correlation between perceived authenticity and grades in Technology? Has the course changed the students' ideas about the future? Do they see themselves as future engineers or designers? We hope to respond to such questions to some extent at the end of the study, after having analysed the questionnaires and interviews with approximately ten students. The pilot study took place during January and February 2016.

Preliminary results and significance of the research

The mapping of the nine elements of authenticity to a IP module (Table 1) and the results of the pilot study will inform the subsequent investigation of implementation of the module at a number of schools, involving more teachers and students.

Table 1. Mapping of nine elements of authentic learning to the design and proposed implementation of an innovation project (IP) module.

Element of authentic learning	Characteristics of the element (based on Herrington, n.d.; Herrington et al, 2010)	Example of proposed implementation of element in the (IP) module
Authentic context	•A design to preserve the complexity of a real life setting. •Provides the purpose and motivation for learning. •Ideas can be explored at length in the context of real situations.	The purpose of the project is a solution to a real-world problem. The task is constructed by the students themselves and has no pre-determined sequence that it should be solved in. Only a few things are mandatory, such as presentation at an exhibition at the end of the IP module.
Authentic task	•Clear goals and real-world relevance. •Require production of knowledge rather than reproduction. •Complex and ill-defined. •Completed over a longer period. •Tasks that can be integrated across subject areas.	The project is presented at an exhibition at the end of the main project. At this exhibition students present their solutions in a business-like manner, trying to interest the visitors in their solution with any appropriate tools such as digital presentations, information leaflets, business cards and verbal communication.
Expert performances	•Access to the way an expert would think and act. •Access to learners at various levels of expertise. •Opportunities for the sharing of narratives and stories. •Expertise is distributed.	Extensive search for information over the internet. The students can contact experts at companies and universities.
Multiple perspectives	•Not just a single perspective - such as a textbook. •Different perspectives of topics from various points of view.	The task should be solved using the best possible sources of information, regardless of whether this is through books,

	•Varied forms of media on the web.	companies, organisations, the internet, or other sources.
Collaboration	•Teams or pairs rather than individuals. •Collaboration encouraged through technology. •Task addressed to groups, not individuals. •Appropriate incentive structure for whole group achievement.	The task is solved in groups of 3-4 students. Documentation is shared within the group, with the teacher, and through Google Docs. The performance of the group, rather than the individual, is the most noteworthy.
Reflection	•Opportunities to make choices. •Students are able to return to any part of the project if desired. •Opportunities to compare themselves with other students and experts.	Since all work is done within the group and over a significant time, there is plenty of opportunities for discussionand reflection during the process. At the exhibition the students evaluate the other groups' work. The evaluations are compiled by the teacher and the result is handed to the group members. After the exhibition, the students write individual reports on the project and reflect on what they have achieved and what they would have altered.
Articulation	•Public presentation of argument to enable defence of position and ideas.	The students prepare a professional presentation of their project at the exhibition. And present it roughly as many times as there are students present. This is especially demanding if there is an external professional present. Besides the oral presentation, they have to produce digital presentations, e.g. Power Point slides, leaflets and a technical report. It is important that the finished product or service is as professionally presented as possible.
Metacognitive support	•No attempt to "transmit" knowledge. •Teacher's role is supporting rather than didactic. •Collaboration where more able partners can assist.	The teacher's prime task during the project is to provide scaffolding support for students, principally at the metacognitive level. No real teaching should take place during the IP module.
Authentic assessment	•Seamless integration of assessment and task. •Opportunities to craft polished	The finished product / service is assessed primarily by other students, but preferably also

performances.
•Significant student time and effort in collaboration with others.

by an external professional. If the project is successful, it is also possible to enter innovation competitions such as *Blixtlåset*, where the project is scrutinised by a professional jury.

Initial analysis of the level of authenticity as perceived by the students, showed an average of 65%, which incidentally, is similar to a study conducted by Bozalek *et al.* (2013) in a South African context (see Figure 2 and 3). The Radar chart (Figure 4) provides an easy-to-evaluate representation of the projects investigated in the pilot study.
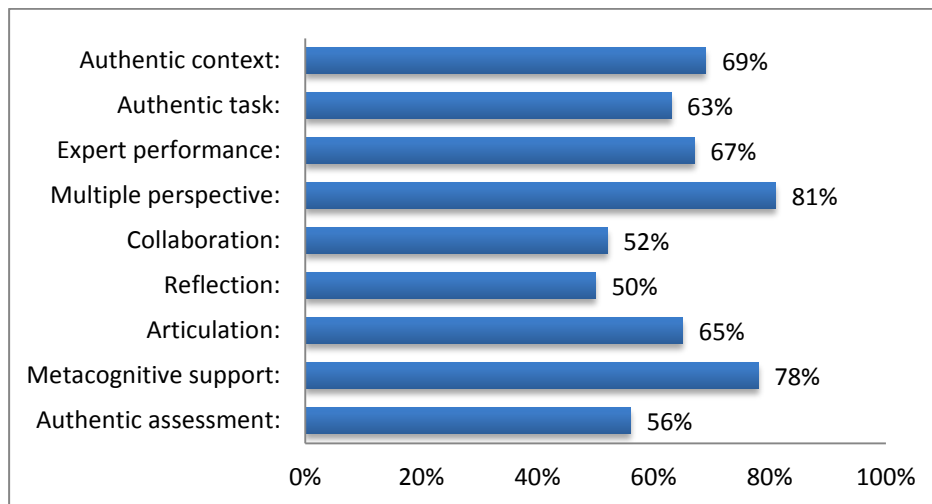

Figure 2. Level of authenticity per authentic learning element. Pilot study February 2016.
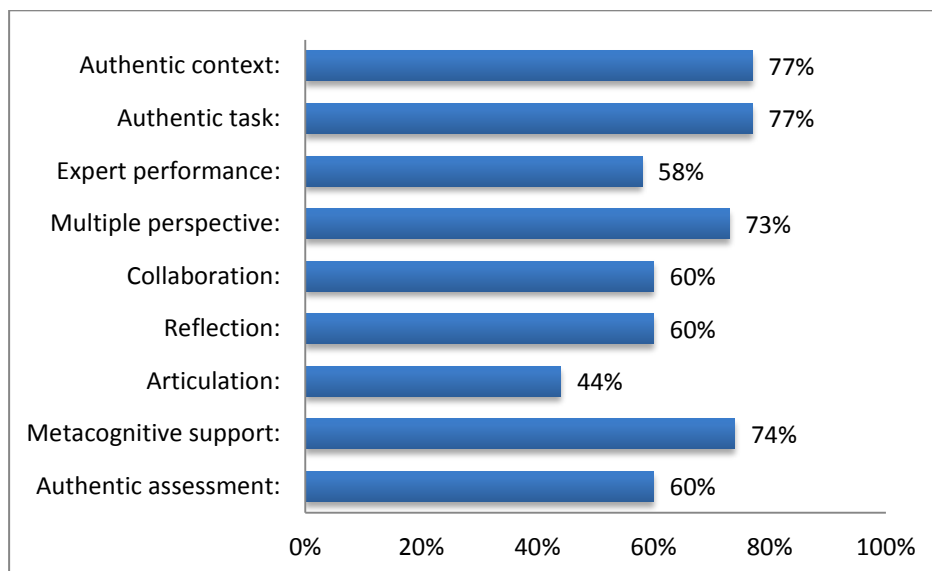

Figure 3. Level of authenticity per authentic learning element. Bozalek *et al.* (2013, p. 634).
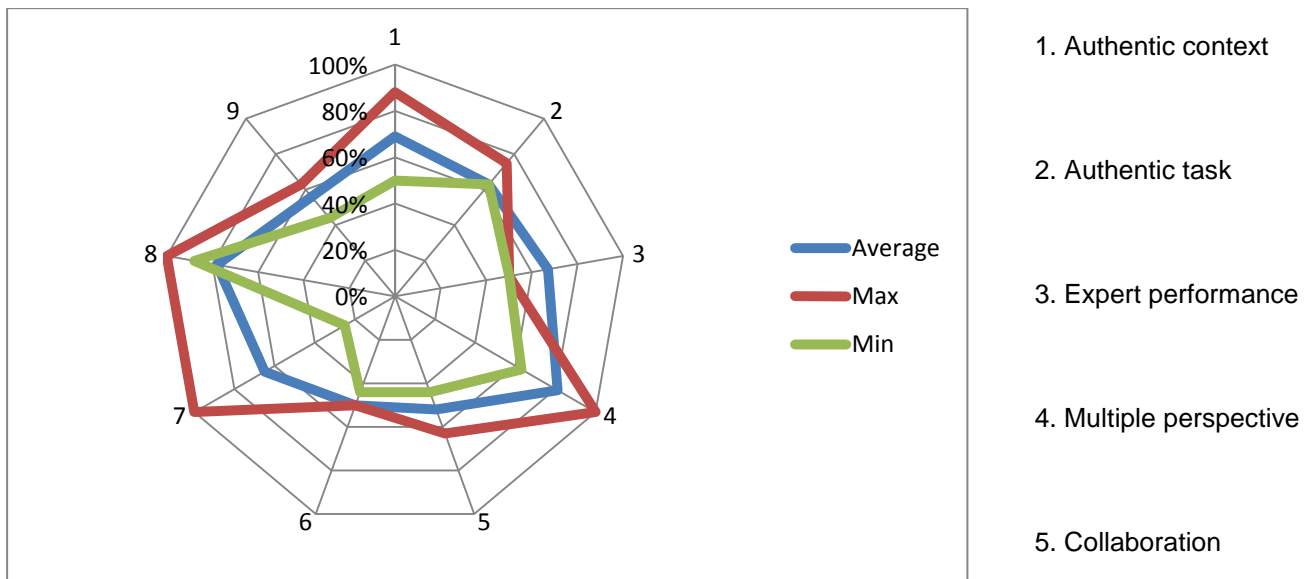
Figure 4. Level of perceived authenticity per authentic learning element. Pilot study February 2016.

The evaluation of the pilot study followed the same principles as the South African study. Each parameter was given 0 to 2 points for level of authenticity by the group members, where 0 represents unauthentic result, 1 week signs of authenticity and 2 strong signs of authenticity. This results in an average score that was then divided by the maximum score, two. Figure 2 presents the average level of authenticity among all the participating groups in the pilot study. In figure 4 we present the same average levels of authenticity plus the group claiming the lowest and the highest levels of authenticity, for comparison. In the South African study the results come from 21 groups of students at different South African Universities, selected for showing signs of authentic learning. In the Swedish pilot study the data comes from all 13 groups of upper-secondary school students involved in the IP.

If any positive correlation between authentic learning in technology and measured results among the students (e.g. grades, enthusiasm etc.) is delivered, it could have implications for the teaching of technology in Sweden and elsewhere.

Implications and Future research

Authentic learning, as presented by Herrington's framework, provides a theoretically based definition that can be applied to inform the design of group activities that result in engaging, complex, and real-life tasks for students to act upon and find solutions to. Pilot study results indicate that the students were satisfied with the outcomes of the IP module. One compelling implication emerging from the pilot study is that students that entered the project having low self-esteem performed better than expected. Exploring implementation of the authentic learning module in the upcoming main study will aim to represent Turnbull's (2002) assertion:

Authentic learning in technology education means that students need to be involved in practices which reflect understanding of the culture of real technological practice. Skills and knowledge are far less relevant and meaningful if taught in isolation. Students need to, and have a right to, understand the relevance and place of their learning (Turnbull, 2002, p. 39).

Unfolding future studies in the project will continue to pursue the question: Can an authentic innovation project module promote a deeper understanding and engagement in technology education, resulting in a genuine interest within students and meaningful learning outcomes?

References

Beghetto, R., & Kaufman, J. (2014). Classroom contexts for creativity. *High Ability Studies, 25*(1), 53-69. DOI: 10.1080/13598139.2014.905247

Bozalek, V., Gachago, D., Alexander, L., Watters, K., Wood, D., Ivala, E., & Herrington, J. (2013). The use of emerging technologies for authentic learning: a South African study in higher education. *British Journal of Educational Technology 44*(4), 629-638. DOI:10.1111/bjet.12046

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*(1), 32-42.

Ciolan, L., & Ciolan L.E. (2014). Two perspectives, same reality? How authentic is learning for students and for their teachers. *Procedia - Social and Behavioral Sciences 142*, 24-28. DOI: 10.1016/j.sbspro.2014.07.581

Collins, A., Brown, J.S., & Newman, S.E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L.B. Resnick (Ed.), Knowing, learning and instruction: Essays in honour of Robert Glaser (pp. 453-494). Hillsdale, NJ: LEA

De Vries, M., Hacker, M., & Burghardt, D. (2010). Teaching technology and engineering. *Technology & Engineering Teacher*, *70*(3), 15-19.

Fox-Turnbull, W. (2006). The Influences of Teacher Knowledge and Authentic Formative Assessment on Student Learning in Technology Education *International Journal of Technology and Design Education,16*, 53–77. DOI: 10.1007/s10798-005-2109-1

Hennessy, S., & Murphy, P. (1999). The potential for collaborative problem solving in design and technology. *International Journal of Technology and Design Education, 9*(1), 1-36.

Herrington, J. (n.d.) Authentic learning. Retrieved November 10, 2015 www.http://authenticlearning.info/AuthenticLearning/Home.html

Herrington, J., Reeves, T.C., & Oliver, R. (2010). A guide to authentic e-learning. New York: Routledge ISBN 0-415- 99800-X.

Herrington, J., & Parker, J. (2013). Emerging technologies as cognitive tools for authentic learning. *British Journal of Educational Technology, 44*(4), 607-615. DOI:10.1111/bjet.12048

Kimbell, R. (1997). Assessing Technology International Trends in Curriculum and Assessment, Open University Press, Buckingham.

Lombardi, M. (2007). Authentic learning for the 21st century: An overview. (*ELI paper 1: 2007)* D.G. Oblinger, Ed. Boulder, CO: Educause Learning Initiative.

Newmann, F.M., Bryk, A.S., & Nagoka, J.K. (2001). Authentic intellectual work and standardized tests: Conflict or coexistence. Improving Chicago's schools. Chicago: Consortium on Chicago School Research. Retrieved from http://ccsr.uchicago.edu/ publications/p0f02.pdf

Nicholl, B, Flutter, J, Hosking, I., & Clarkson, P.J (2013). Joining up the DOTs: authentic teaching and learning in Design and Technology education. *Cambridge Journal of Education*, *43*(4), 435–450. DOI: 10.1080/0305764X.2013.811219

Reeves, T.C., Herrington, J., & Oliver, R. (2002). Authentic activities and online learning. In A. Goody, J. Herrington, & M. Northcote (Eds.), *Quality conversations: Research and Development in Higher Education*, (Vol. 25, pp. 562-567). Jamison, ACT: HERDSA.

Rotherham, A. J., & Willingham, D. T. (2010). "21st-Century" Skills. *American Educator*, *34*(1), 17-20.

Skolverket (n.d.) www.skolverket.se, retrieved November 15, 2015.

Snape, P., & Fox-Turnbull, W. (2013). Perspectives of authenticity: implementation in technology education *International Journal of Technology and Design Education, 23*, 51–68. DOI 10.1007/s10798-011-9168-2

Turnbull, W. (2002). The place of authenticity in technology in the New Zealand curriculum. *International Journal of Technology and Design Education, 12*(1), 23-40.

Weimer, M. (2013). Learner-centered teaching: Five key changes to practice (2). Somerset, US: Jossey-Bass. Retrieved from http://www.ebrary.com

Student attitudes toward technology: what is hidden behind the survey answers?

Svenningsson, Johan
Linköping University
Norrköping, Sweden
johan.svenningsson@liu.se

Hultén, Magnus
Linköping University
Norrköping, Sweden
magnus.hulten@liu.se

Hallström, Jonas
Linköping University
Norrköping, Sweden
jonas.hallstrom@liu.se

Abstract

The *Pupils' attitudes towards technology* survey (PATT) has been used for 30 years and is still used by researchers. Since first developed, validity of the questionnaire constructs have primarily been discussed from a statistical point of view, while few have discussed the type of attitudes and interest the questionnaire measure, and in what way.

In order to contribute to an increased understanding of the PATT results we present six 14-year-old Swedish students and their results in the PATT-SQ survey, as well as their thoughts about why they responded to the survey as they did. This is to be able to understand what the student attitudes and interest in technology might mean. In this paper we focus on the categories; *Interest, Career* and *Gender* and the students' interpretations of the statements and the Likert-scale. These six students completed a Swedish version of the PATT-SQ three weeks prior to a 15 minute semi-structured interview.

Even though most of the interviewees use interest as a synonym to enjoyment, this lack of distinction does not seem to affect the survey result. Our interpretation is that the respondents describe interest (and/or enjoyment) as a well-developed interest. An urge for a technological career equals working as an engineer or architect among these interviewees. Those who do not want to pursue such a career refer to this career, rather vaguely as technician. There seem to be an impact from other sources than school, which create this difference in career aspirations. Finally the gender category cannot be used by calculating the mean, since students' tend to use the same option generally on the Likert-scale independently of how the how the statements are posed.

Introduction

The study of *pupils' attitudes towards technology* (PATT) has a long history in technology education research. The PATT questionnaire was developed in the 1980s by Raat and de Vries (1986). Their intention was to explore students' interest and attitudes towards technology. It was considered important to use the data for strengthening the subject's status and display that technology as a school subject was important for younger children as well. In the PATT questionnaires students' attitudes towards the technological field are surveyed from a range of perspectives: like their

career aspirations in technology, interest in technology and technology education. The first results from the PATT studies showed, for example, that girls found technology less interesting and less important than boys did (Boser et al., 1998).

Research in attitudes towards technology (and attitudes in general) often aims to find factors that can predict a student's attitude, such as their parents and family, gender, socioeconomic background and teachers etc. (Davies & Brember, 2001; Lindahl, 2003). The PATT survey has often been used to point out gender differences in attitudes towards technology (see e.g. Hendley, Stables, Parkinson, & Tanner, 1996; Volk & Ming, 1999; Bain & Rice, 2006). This is also the case when adding attitudes towards science (and technology) as reported in a systematic review by Potvin and Hasni (2014) where gender differences is the most common theme in their reviewed articles. Potvin and Hasni (ibid.) also mention career as a videly researched area.

Since the first PATT studies, the questionnaire has been used on pupils in a range of different countries across Asia, Africa and Europe. The PATT questionnaire has evolved since the beginning, first by Bame and Dugger (1989) and recently it has been shortened (Ardies, De Maeyer, & Gijbels, 2013) to consist of fewer items and re-named PATT-short questionnaire (PATT-SQ). Validity of the questionnaire constructs have primarily been discussed from a statistical point of view, while few have discussed what type of attitudes and interest that the questionnaire measure. Even though the first round of PATT studies in the 1980s went through rigorous validation and reliability tests, the past 15 years have resulted in few discussions concerning the survey's validity and reliability, more than controlling the survey's internal reliability with Cronbach's α and confirming unidimensionality by factor analysis. This can of course tell us a lot of the survey's internal consistency and the distinction of the different categories, though some problematics have been observed despite these statistical tests. In e.g. South Africa, when researchers using the PATT-questionnaire experienced language difficulties within their context, especially regarding the understanding of the word technology (Van Rensburg, Ankiewicz, & Myburgh, 1999) Similar problems occur in the Swedish language since the word technology (Swedish *teknik*) can have the same meaning as the word skill or technique (cf. Mitcham & Schatzberg, 2009). In the same South African study by Van Rensburg et al. (1999) the gender items are pointed out as problematic since they are non-neutrally expressed.

To be able to use data in research we need to understand what the PATT-survey can tell us about a students' attitude within the different survey categories and how students interpret the survey. Therefore, in this paper the following research questions are posed:

How do students' interpret the different items within the categories in the PATT-SQ survey?
What can the PATT-SQ mean score tell us about a student's attitude?

Taking previous research into consideration, focus in this study will be on problematics as discussed by Van Rensburg et al. (1999) and the fact that gender and career aspirations are two of the most researched areas (see Potvin & Hasni, 2014) together with the interest construct which can be seen as both a field by itself and a construct within attitudes.

Both attitudes and interest can be seen as motivational variables (Krapp & Prenzel, 2011) and interest can be seen as a construct within a person's attitude (de Klerk Wolter, 1989). On a more general level some studies have found that interest in a subject can correlate positively with knowledge in that subject, especially in higher grades (Krapp, 1999) and in some cases attitudes toward technology positively correlates with a students' knowledge (Gamire & Pearson, 2006).

Attitudes

Attitudes can be seen through three components; affective, cognitive and behavioral. Attitudes towards an object are based on a person's beliefs about the same object and those beliefs have influence on the behavior (Fishbein & Ajzen, 1975).

The PATT survey is suitable for assessing a students' affective component (Van Rensburg et al., 1999). This means that the students' emotional engagement in technology and technology education is surveyed.

Interest

A persons knowledge can at any time become an object of interest (Krapp, 2002). It can be stated that an interest has to be towards something, for example technology education (Krapp et al., 2011) and it can be seen as a motivational factor for getting engaged within the subject (Hidi & Ann Renninger, 2006; Krapp, 2002). Interest can be divided into *Situational Interest* and *Individual Interest.* Situational interest can take place in a specific situation that will trigger an interest, while individual interest is based on the persons own underlying beliefs (Hidi & Ann Renninger, 2006).

The PATT-SQ surveys' statements regarding interest are focusing on the will to gain more knowledge especially through school technology. A high mean score on the interest scale should therefore indicate; a well-developed individual interest in the four phase model of interest as presented by Hidi and Ann-Renninger (2006).

Method

To be able to understand students' interpretations of the PATT-SQ we conducted interviews with six 14 year olds (3 boys and 3 girls). The interviews were conducted after the survey and focused on questions concerning problems or potential misunderstandings when completing the survey. We conducted semi-structured interviews with the survey as a base for the questions, to let the respondents speak more freely about the different topics. The intention was to extract more information from the respondents than the survey would if using a structured interview method (Robson, 2011).

The used PATT-SQ survey (Ardies et al., 2013) consists of 24 items within six different categories or attitude scales: **Career –** Respondents' career aspirations in technology; **Gender –** Gender patterns in technology; **Consequences –** Consequences and importance of technology; **Interest –** Interest in technology and technology education; **Difficulties –** Perceived difficulty in the technology subject; **Boredom –** Perceived boredom with technology. The students respond to each of the 24 statements on 5-graded Likert-scale ranging from agree (1) to disagree (5). As mentioned this study focuses on the categories Career, Interest and Gender.

The survey has been translated from English and adapted for a Swedish context with acceptable internal consistency within the categories (Svenningsson, Hultén, & Hallström, 2015). The Cronbach's α was either above .7 as recommended by Lovelace and Brickman (2013) or has an inter-item correlation mean between .2 and .4 as recommended by Briggs and Cheek (1986). However, questions were raised regarding some of the categories. Considering the previous results by Svenningsson et al (2015) two different word sequences in the gender category was used, resulting in six statements (original three, cf. Ardies et al., 2013). The students answer to the original statements such as "*Boys are more capable than girls… "* referred to as *Gender M,* and the opposite statements *"Girls are more capable than boys… " Gender F.*

Data collection

The interviewees were chosen by their teacher to represent different student types as perceived by the teacher (high/mid/low achievers, high/mid/low interest). The PATT-SQ survey was completed

three weeks prior the interview. All six students belong to the same school class and have the same teacher in technology, this to exclude the natural variety between schools. Therefore all students have participated in the same technology education class, conducted by the one teacher. They had all participated in technology lessons at age 13, but not during their current semester.

Data analysis

The audio-recorded interviews were transcribed and all student answers were labelled according to the PATT-SQ survey categories (e.g. Career, Interest, Gender) in MAXQDA. This to detect underlying thoughts about career, interest and gender issues, where questions have not been specifically directed towards these topics.

Ethical considerations

All participants were informed about the study, its' use and their right to choose to participate or not. All interviewees agreed to participate in the interview and their legal guardians approved of their participation.

Results

The six students' mean score in the chosen categories (Career, Interest and Gender) were calculated and is presented together with their interview responses to each of the categories. These mean scores only serve as a marker to be able to see some connection between the spoken word and the answers in the survey.

The survey

First of all we find it important to know how the students interpret the 5-graded Likert-scale and especially the middle option. They were all asked to explain the middle option to the interviewer and typical answers were:

"It's when you don't know if you agree or disagree."

"They are like, I'm not certain, you might think both sides and don't know what to choose."

"That you're not sure if you agree or not."

All of the six interviewed students agreed, independently, on how they filled out the survey and chose option on the Likert-scale. Their interpretations of the Likert-scale are similar and they use the middle option when they do not know if they agree or disagree.

The interviewees

The six interviewees are presented below with their mean score and their thoughts about the topics: their technology career aspirations, their interest in technology and thoughts of technology as an activity for both girls and boys. To get an overall picture and see a progression of the interviewees, they are presented from low to high career mean and a small summary is presented below every student interview.

Interviewer questions = **R**
Respondent answers = **G/B (**Girl/Boy) followed by the respondent number

Girl 1
Career mean 2.00

"I'm pretty confident that I won't be working with that [technology], I'm not really sure that I know what a technician might do…When I think of a technician, I think of someone sitting in front of a computer and that might be why I don't want to work with it. You might work in a factory

perhaps, that produces something. I really don't know much about this, maybe that's why I'm not that interested."

Interest 2.83
"I think technology is interesting but I don't find it enjoyable, it doesn't really cohere, I know…I believe that smartphones and stuff, that is technology, and I find that interesting… I kind of use my smartphone every day, then I learn, but if I don't understand, it wouldn't be as fun."

Gender M 4.00 Gender F 3.00
"I believe, the reason that boys are more common in technological jobs I think is because they have a greater interest than girls. I really think that is the only reason, because I think girls can perform just as well if they are more engaged"

These answers can tell us that she is not interested in pursuing a technological career, which reflects her answers in the survey. Since she is not sure of what a technological job might be she doesn't want to rule out the possibility completely. This girl struggles with her thoughts of the fact that some technology is interesting, in this case the technology she understands and uses. Her knowledge about her smartphone leads to her interest in the same. The same argument is repeated when she talks about technology for both boys and girls. She believes that boys are more common in technology-related work because more girls have a lack of interest in technology.

Girl 2
Career mean 2.50
G1: *"I haven't got a clue [what a technological profession might be], but maybe if you want to be like a carpenter, you need to be like handy…If you want things to function together, like screws and nuts…but like a plumber, since they kind of need to understand what is wrong and make it work again"*

R: *"Would you like a job as a plumber?"*

G1: *"Not plumber specifically, but if I don't like technology, then maybe I shouldn't work with it, then I might begin to like technology first."*

Interest mean 2.67
G1: *"It is one of the more enjoyable school subjects [technology], because you get to work with your hands…after history, English, arts and French."*
R: *"Where does the interest in a school subject come from?"*
G1: *"It has to do with what you as an individual like doing, if you like it you become more interested…and more engaged with the subject… sometimes influenced by friends, but not for me, and sometimes by teachers who make it fun."*
Gender M 1.00 Gender F 1.00
"Boys and girls are kind of the same, they have equal knowledge about technology. It is not like someone knows more about technology. Well I know that some people believe that boys are better at stuff, but I don't think so, I can't understand why they think that"

This girl says that she does not know what a technological job might be, but after reflecting for a while she discusses the work of a plumber as technological which is not a career path for her. She has a relatively low mean score regarding interest whilst she finds it interesting. Technology is likely to be a "middle" subject, not favorite or least favorite which is reflected in her score. She is also slightly offended by the thought that boys might be better at stuff, only because they are boys.

Boy 1
Career mean 3.00
B1: *"Maybe technician."*

R: *"What do they do then?"*

B1: *"They are connecting cords and stuff, maybe?"*

Interest 3.50
"I think it's fun [technology], it's kind of practical stuff and that is always fun…Well it's like when we are talking in class and listen to the teacher talking about interesting things and stuff that I didn't know before…I enjoy other subjects as well, but don't find them as interesting…my interest comes from the school teaching."
Gender M 3.00 Gender F 3.00
"I believe it depends from person to person, a girl might be better than, or a woman might be better at a job than a man. It kind of varies, it depends on the person."

This boy is repeating his reflections of technicians working with cords and connecting them throughout the interview and refers to technology as something that has to be electric. He also mentions a distinction between interest and enjoyment. His interest is strictly connected to the experiences from school technology and teacher lectures. Regarding the gender items he is very clear about the fact that differences are between people, not their sex.

Boy 2
Career mean 4.25
"Maybe architect, or engineer, or like when you draw different stuff so you can push computers to their limit…Those jobs seem fun, I want to work with that in the future…Most jobs have something to do with technology…like if you are an electrician you need a good technique [Swedish teknik] when connecting cords to an alarm as well as a carpenter."

Interest 3.67
"Well I have always been interested in computer technology and football where I use a lot of technique [Swedish teknik].
Gender M 3.67 Gender F 2.33
"I think that boys might be more inventive in technology, but there are girls who are as well. Boys might be more interested in technology and chemistry and stuff."

This boy is definitely interested in a future career within technology. He mixes the use of the word technology as both technology and skill/technique. This makes it harder to interpret whether his interest might be connected to his interest in football. He draws the conclusion that there are individual differences and not sex differences in technology, but explains his mean scores by talking about a larger number of boys being interested in technology and therefore more boys might be better at technology.

Boy 3
Career mean 4.25
"Well, I believe that I would enjoy being an engineer and come up with ideas to different inventions, because I like being creative in that way…I'm kind of knowledgeable in technology and stuff, so I think I have a good chance working with it, I think that I would enjoy that."

Interest 3.83

"My interest comes from playing a lot of video games as a kid... and using computers, wanting to know how to make and editing movies and stuff... I used to watch videos on YouTube to learn... I live outside of the town center and didn't have a lot to do and was always interested in how things functions... My friend's dad works with computers and he has taught me a lot, it has always been fun working with computers and stuff."

Gender M 3.33 Gender F 2.67

"I didn't know it was between these two. I would have hoped that it could be something in between. But I was thinking like this: from my perspective, girls haven't been exactly as good as boys, that I know of. But as whole, some might do, and many [girls] could know more."

This boy believes that his knowledge together with his enjoyment in technology will help him to work as an engineer or inventor. He thinks that his interest has emerged out of boredom and his need of a hobby. This interest has evolved and he has gotten more involved in how computers work through his friend's dad and by watching YouTube. Regarding sex differences he believes that they are individual but historically more boys work with technology and therefore in general might perform better.

Girl 3,
Career mean 4.75

G3:   *[A technological career is] engineer, or like an architect or something."*

R: *"Why would you want to work with technology?"*

G3:   *"Because it pays good money (laughter), no maybe because I find it interesting and stuff, my dad is an engineer so I have seen what he is doing."*

Interest 4.33

*"I don't know where the interest comes from, I have kind of always been interested in technology and of course there is L****, she is a good teacher... I think it has to do with, when you're good at something it becomes more fun."*

Gender M 1.00 Gender F 1.00

"Like in technology class, it depends on how much you have learned."

This girl has a really high mean for career aspiration and she believes that she has a good knowledge of technology. This is also how she explains her interest, where knowledge follows interest. Even though her dad is an engineer she does not really explain what he does for a living or think of him as an influence to her interest. Finally she believes in no differences between the sexes in technology, instead she explains variety to depend on knowledge.

Result summary

The intention of this paper is to draw conclusions of how accurate the survey is, when comparing interview answers to the student's survey answers. First of all the students' interpretations and use of the Likert-scale is used as intended. The three categories studied are presented with a short conclusion.

Career – The high-mean students (>4.00) in this study all refers to a technological career as an engineer and architect. The low-mean students (<3.00) use the word technician for technology-related work and in the interviews these students urge to explain what they mean in detail. The high mean students on the other hand seem to be satisfied to only use the words engineer or

architect. The interviews show that independently of whether you understand what a job in technology is or is not, a high mean describes an urge to pursue such a career. Whilst the low mean students are not willing to totally cut off that future path, mostly because they are uncertain of what it means. The high-mean students' do not give a clearer view of what this career might be

Interest – The interviewees commonly refer to interest like; a subject is interesting since they find enjoyment within the subject. There are some of the students who state a difference between interest and enjoyment on the other hand there is only one statement in the interest category that actually contains the word interest. What they consider to be technology affects the students' mean score, but these students have only had a very limited amount of technology education and they are still not clear about what the school subject is about. On the other hand both high- and low-interested students describe that an interest makes you willing to learn more or the other way around, knowledge is followed by an interest.

Gender – The Gender category is supposed to tell us if the respondent experience technology as an activity for both boys and/or girls. The interviews show that the mean score is unreliable and does not reflect the students' thoughts of technology as an activity for both boys and girls. This because some respondents believe this has to do with individuals rather than sex, which explains why they choose the *disagree* option or *not sure* option consistently. However some of the interviewed students indicate that there might be differences, but mostly connect this either to the fact that more boys are active in technological careers or has a higher interest and therefore perform better in technology.

Conclusions

To conclude, the interviews made with students in this study does not point to any validity problems of the questionnaire, the students seems to understand most of the questions in the intended way and how to position their answers on a Likert-scale. One student *(boy 2)* lacks a distinction between technology and skills (see Mitcham & Schatzberg, 2009) when he discusses football skills and the technicue an electrician use when connecting cords. This could be problematic, since it is difficult to interpret which of these meanings is referred to when completing the survey. This is a problem that several other countries should also encounter and that the researcher needs to be aware of when using the survey (cf. van Rensburg *et al.*, 1999).

Among these six students there seem to be connections between their expressed lack of knowledge about technology/technological careers and their mean scores. This might be affected by the fact that these students have had very limited amount of technology classes. Most of the answers are reflections considering either their spare time interest or family members' jobs. The students who score low mean scores on interest and career do not have a clear explanation for why they have this low score. The students' descriptions of interest are similar to what would be considered a well-developed individual interest (Hidi & Ann Renninger, 2006). How they place themselves on the Likert-scale (1-5) indicates how deep the students' well-developed interest is perceived.

As mentioned, gender is one of the most studied variables when researching attitudes. This is of course since you often find distinct differences when comparing sexes. The gender category is however not meant to explore these differences. This category has to do with how the respondents perceive differences rather than how we as researchers compare the sexes. As a category it is unreliable and cannot be used only by calculating means, hence an indication of direction is noticeable when comparing the answers using the opposite stated items as done in this study (Gender M and Gender F). The interviewees also let us know that they tend to agree that boys might be more capable with technology related tasks, meaning that there are more boys than girls that are capable.

Finally the PATT-SQ survey let us know that it does detect the high interest students and students pursuing a technological career, at least among these six students. While the low interest students responses mainly seem to depend on a lack of knowledge. This should be taking in account when using and analyzing results from the survey. Of course a high interest and a will to pursue a technological career are desirable. But since the low mean scores seem to be correlated to the student understanding and knowledge it might be difficult to use the low mean scores in these categories to draw conclusions. The students' knowledge and out of school experience regarding technology seem to be key factors that affect their attitude score. Even though this is a small sample of students, they can still tell us how they interpret the survey and give us an indication of what the PATT-SQ measure and what problematics in need for consideration when using the survey.

References

Ardies, J., De Maeyer, S., & Gijbels, D. (2013). Reconstructing the pupils attitude towards technology-survey. *Design and technology education: an international journal, 18*(1), 8-19.

Bame, E., & Dugger, W. (1989). *Pupils' attitudes toward technology, PATT-USA, a first report of findings.* Retrieved 09 01, 2014, from http://www.iteaconnect.org/: http://www.iteaconnect.org/Conference/PATT/PATTSI/PATT%20USA.pdf

Boser, R. A., Palmer, J. D., & Daugherty, M. K. (1998). Students Attitudes Toward Technology in Selected Technology Education Programs. *Journal of Technology Education, 10*(1), pp. 4-19.

Briggs, S., & Cheek, J. (1986). The role of factor analysis in the development and evaluation of personality scales. *Journal of personality, 54*(1), 106-148.

Davies, J., & Brember, I. (2001). The closing gap in attitudes between boys and girls: a 5-year longitudinal study. *Educational Psychology: An International Journal Of Experimental Educational Psychology, 21*(1), 103-114.

de Klerk Wolter, F. (1989). *The attitude of pupils towards technology.* Eindhoven, Nederländerna: Eindhoven University of Technology.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: an introduction to theory and research.* Reading, Mass.: Addison-Wesley, cop. 1975.

Gamire, E., & Pearson, G. (2006). *Tech tally : Approaches to assessing technological literacy.* National Academies Press.

Hallström, J., Hultén, M., & Lövheim, D. (2014). The study of technology as a field of knowledge in general education: historical insights and methodological considerations from a Swedish case study, 1842-2010. *International Journal Of Technology & Design Education, 24*(2), 121-139.

Hidi, S., & Ann Renninger, K. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111-127.

Krapp, A. (1999). motivation and learning: An educational-psychological perspective. *European Journal of Psychology of Education, 14*(1), 23-40.

Krapp, A., & Prenzel, M. (2011). Research on Interest in Science: Theories, methods, and findings. *International Journal of Science Education, 33*(1), 27-50.

Lindahl, B. (2003). *Lust att lära naturvetenskap och teknik? En longitudinell studie om vägen till gymnasiet.* Göteborg: ACTA UNIVERSITATIS GOTHOBURGENSIS.

Lovelace, M., & Brickman, P. (2013). Best practices for measuring students' attitudes toward learning science. *CBE Life Sciences Education, 12*(4), 606-617.

Mitcham, C., & Schatzberg, E. (2009). Defining Technology and the Engineering Sciences. In *Philosophy Of Technology And Engineering Sciences* (pp. 27-63). Elsevier B.V.

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at k-12 levels: a systematic review of 12 years of educational research. *Studies In Science Education, 50*(1), 85-129.

Raat, J. H., & de Vries, M. (1986). *What do girls and boys think of technology? - Pupils' attitude towards technology.* Eindhoven, Nederländerna: Eindhoven University of Technology.

Robson, C. (2011). *Real world research : a resource for users of social research methods in applied settings.* Chichester: Wiley, 2011.

Svenningsson, J., Hultén, M., & Hallström, J. (2015). Swedish Students' view on Technology: Results from a pilot study using an adaptation of the PATT-SQ questionnaire. In M. Chatoney (Ed.), *PATT 29 Plurality and Complementarity of Approaches in Design & Technology Education, Marseille, France, April 2015.* Marseille: Presses Universitaires de Provence.

The swedish national agency for education. (2011). *Curriculum for the compulsory school, preschool class and the recreation centre 2011.* Retrieved from http://www.skolverket.se/publikationer?id=2687

Van Rensburg, S., Ankiewicz, P., & Myburgh, C. (1999). Assessing South Africa learners' attitudes towards technology by using the patt (pupils' attitudes towards technology) questionnaire. *International Journal of Technology and Design Education, 9*(2), 137-151.

Sustainable development is part of all technology education! - A technology teacher perspective on the relation between technology education and sustainable development

Maria Svensson
University of Gothenburg, Sweden
maria.svensson@ped.gu.se.

Ann-Marie von Otter
University of Gothenburg Sweden
annmarie.von.otter@ped.gu.se

Sustainable development is part of all technology education! - A technology teacher perspective on the relation between technology education and education for sustainable development

Abstract

Technology in today's society needs to be constantly exposed to consequence analyses related to sustainable development. Industries, inventors and educators working with technology development have a responsibility to develop technology that meets the demands of sustainability in terms of ecological, economic and social aspects (Jucker and Mathar, 2015). The emerging global crisis requires educational responses that evolve knowledge about technology beyond single innovations or artefacts towards technological systems that embraces social, environmental and sustainable issues (Elshof, 2009; Pavlova, 2013). Education in technology requires a holistic treatment and at the same time maintaining a connection to everyday life. Regarding the development of technology education this can mean a development of understanding of flows such as matter, energy and information in different systems e.g. mobile phone systems and water and sewage systems (Svensson, 2011). Using a systemic approach in technology education may open for new possibilities to understand the connection between technology and sustainable development.

In this pilot-study technology teachers' perception of the relation between technology education and education for sustainable development (hereinafter referred to as ESD) have been conducted using a questionnaire with open-ended questions. The conventional content analysis (Hsieh and Shannon, 2005) was used on text data. The results indicate that technology teachers in the Swedish compulsory school believe that sustainable development is closely linked to technology and technology education. They describe an understanding of technology and sustainable development as systemic. However, when it comes to the teaching the main activities are described with a focus on products and life-cycle analysis, from raw material to a product, which could be understood as a linear process and thus cannot fully be seen as a systemic approach.

Keywords: technology education, education for sustainable development, technological systems, system approach

Introduction
Technology education can be used as a tool to meet the challenge of sustainable development, but there are still a number of factors that needs to be investigated further on. Two such challenges are identified (e.g. Pavlova, 2013; Pitt and Lubben, 2008): 1) What are the natures of ESD in technology education? 2) What are the teachers' knowledge, beliefs and attitudes? These two challenges are related to the investigation, we would like to carry out in order to highlight *if* and possibly *how* technology education may be a tool for ESD. Technology and sustainable development play an important role in community development and by a pilot study, we want to investigate if and how technology teachers' connect technology education and ESD.

Aim
The aim with this project is to explore technology teacher's perceptions of technology education and ESD through a questionnaire. Further on, we want to reflect their perceptions of the relation between technology and sustainable development with a systemic approach.

Research questions:
- What are teachers' perception of the relationship between technology education and ESD?
- What connections are made to a systemic approach in teachers' perceptions of the relation between technology education and ESD?

Background
In today society artefacts are embedded in technological systems. When we use washing machines and mobile phones they need to be connected to the water supply system, energy systems and mobile operators. A technology system can be described as a number of components that work together for the overall objective of the whole (Churchman and Churchman, 1968). In technology education an understanding of technology as systemic implies an awareness of the structure and the intention and interactions of systems (Koski and De Vries, 2013; Svensson, 2011; Örtnäs, 2007). Important aspects to reflect on in relation to the surroundings is the interactions in systems, the feedback between components and the input and output of the system (Svensson and Ingerman, 2010).

Technology education in Sweden, the context where this study is carried out, is planned and evaluated in respect to five long-term goals: 1) to identify, analyse technology in the surrounding, 2) to identify problems and needs and propose solutions, 3) use technology area concepts and forms of expression, 4) evaluate the consequences of different technological choices for the individual, society and the environment, 5) analyse driving forces behind the development of technology and how technology has changed over time (Skolverket, 2011). In both the long-term goals and in the descriptions of the content in the Swedish curriculum in technology, is the relation between technology and sustainable development discernible. An example from the content descriptions is: "Effects of technology choices based on ecological, economic, ethical and social aspects, for example, in the development and use of biofuels and military equipment" (a content marked under the heading Technology, man, society, environment, for grades 7-9, Skolverket, 2011).

Except that there is a clear link between technology and sustainable development in policy documents in Sweden there are both research and international reports pointing in the same direction, technology and sustainable development can be linked. One reason for combining technology education and ESD, highlighted by Nilsen (2015), are the impact that all technology has on society and nature and sustainability as a tool for building capacity for living and learning. Technology is interwoven in our lives and as Nilsen (2015) claims: "We can like it or not, but technology has totally invaded our lives, and so it is with the nature" (p.99).

ESD have been essential in a lot of international reports and highlighted as a critical aspect of promoting sustainable development. ESD is described as the integration of the three dimensions referred in UNESCO (2009): the *socio-cultural* dimension, the *environmental* dimension, and the *economic* dimension. ESD is an education that seeks to balance human and economic well-being with cultural traditions and respect for the Earth's natural resources (Wals and Keift 2010). It emphasizes aspects of learning that enhance the transition towards sustainability, including future education; citizenship education; education for a culture of peace; gender equality and respect for human rights; health education; population education; education for protecting and managing natural resources; and education for sustainable consumption (Wals and Keift 2010).

Research concerning technology education and ESD exists, but is not among the mainstream topics of research agendas (Pavlova, 2013). Studies of technology education and ESD are mainly discussed and focused on ecological design of products and the environmental impact or sustainability of products (Elshof, 2003; Stables 2009). The social and cultural aspect of ESD is insufficient in technology education research. If economic aspects of ESD occur in relation to technology education, it is described mainly as something negative and in relation to developed countries (Elshof, 2003). Filho, Manolas and Pace (2008) investigated initiatives in schools and universities that exemplified existing practices where technology education and ESD have been integrated. They emphasize two inter-related characteristics of the subject technology, "(a) that it is not just a know-how subject, but a know-why subject […] and (b) that it provides students with the opportunity to resolve problems and hence extend human capabilities." (p. 161). This implies that technology education must become more student-centered and include a more interdisciplinary approach to integrate various issues, including sustainability. However, there is a lack of research on teaching and learning in and about technology connected to sustainable development, in particular regards the social, cultural and economic nature of sustainability. In order to provide additional insights in this direction; we want to investigate the relation between technology education and ESD through a systemic approach.

A systemic approach is about reducing something to look at its parts, reductionism, as well as seeing parts as related to something whole, holism (Ben-zvi-Assarf and Orion, 2005). Senge (1990) suggested that system thinking is a school of thoughts that focuses on recognizing the interconnections between the parts of a system and then synthesizes them into a unified view of the whole. Using a systemic approach to understand technology or sustainable development implies a focus on the processes used to determine the outcomes of content or a procedure based on the experiences of well-defined and repeatable steps and an evaluation of the results. In education a systemic approach is of particular value in the problem solving situations where it is important to have a capability to enlarge the systems' borders and expose hidden dimensions of the system (Ben-zvi-Assarf and Orion, 2005).

Method
We investigate teachers' understanding of the relation between technology education and ESD by using conventional content analyse. Content analysis can be used with a study design whose aim is to describe a phenomenon normally thru an analyse on text data (Hsieh and Shannon, 2005). We find this research method appropriate in relation to our interest, which is to explore teachers' preconception by letting them write answers in an open-ended questionnaire. The questionnaire will allow us to conduct the study repeatedly against a defined group to gather information The advantage of the conventional content analysis is gaining direct information from the participants without imposing preconceived categories. A disadvantage with the method is failing to develop a complete understanding of the context of the answers, we try to avoid this by triangulation.
The empirical material in the study is conducted thru a questionnaire, with 7 questions about the meaning of sustainable development for them as teachers and how they integrate sustainable

development into their technology teaching and how they describe the linkage between technology systems and sustainable development from a teaching perspective. The study presented in this paper is based on a pilot study with 14 teachers involved. The teachers teaching from grade 0 (pupils 6 years old) to grade 9 (pupils 15 years old) and they have voluntarily chosen to join a training course in technology. The questionnaire was distributed to the group of teachers as a Google form document in the end of one of their lessons during the course. The answers are anonymous, we are not interested in individual response, but by a group of teachers' perceptions.

In the analysis of the written answers have both authors read, independently of each other, the answers repeatedly to achieve a deeper understanding and obtain a sense of the holistic approach. In the initial analyses both authors' makes notes of key concepts from the questions. The key concept that emerges in the analysis are environmental, global, systems, from raw material to a product, process and life cycle. After a comparison of the identified key concepts tentative categories emerges. These categories are then used when revisiting the data to sort how the categories are related and linked. When more solid categories have been developed the categories are tested, with a group of researchers in science and technology, to explore whether they describe teachers' perceptions of the relation between technology education and ESD. Since results presented in this paper come from relatively few participants, we intend to do an expanded study with about 30 teachers in 2017.

Result

The results overall show that all participants believe that there is a relation between technology education and ESD. Three categories that describes how the teachers perceive the relationship between technology and sustainable development from a systemic approach was identified:

A. Sustainable development as part of technology
B. As a life-cycle analysis
C. As a system

A. Sustainable development as part of technology

This category represents a few answers and focusing on that everything in technology is connected to sustainable development.

"Basically, in all areas in technology and in all grades"

"In everything … it is the "red string" in technology."

In the excerpt no specific issues or content in technology is mentioned, but indicate a general attitude about technology and sustainability as related.

The reasons mentioned for the integration are that technology's impact on nature.

"Technology requires intervention in nature, new technology helps so we get more efficient methods, sustainability thinking drives the technology into new methods of production and use."

There are indications that some of the teacher's in this pilot study considers technology to be the driving force for sustainable development.

B. As a life-cycle analysis

A lot of answers describe a strong relation between technology and sustainable development as the production process, from raw material to a useable product, and in some cases extended to

include a recycling perspective. We interpret this as a life-cycle analysis. With a strong focus on the materials used in a production process.

"According to me, the use of materials is connected to sustainable development in different technology areas such as: construction, transport, communications, control engineering and process technology"

"Life cycle analysis of products, the relationship between the planet's resources and how we use them – e.g. consumption, small scale consumption versus large scale and how technology can help us into the modern small scale consumption."

In the first excerpt we interpret a life-cycle analyse of materials when the use of materials is focused and related to different areas in technology education. In the other excerpt life-cycle analyses are mentioned and related to materials, the planet's resources.

Similar as in category A, the teacher's describe the relation between technology and sustainable development as the impact that technology has on nature. Thus, in this category with more focus on natural resources used in a production process.

C. As a system
The focus in this category is on the relation between technology and sustainable development as the integration of a life-cycle, from raw material to a useable product, with society and the environment. In this way a systemic view of parts and whole emerges.

The following expert contains words that indicate an understanding of production processes as something more than a life-cycle in that there are words as: "power to decide" and "impact on the producing country".

"Raw materials, assets, source, power to decide, transportation, impact on the producing country. The production process. After use, what happens then"

The relation to life-cycle analysis is remaining, but an opening towards other systems and society is visible.

In the next excerpt we interpret a holistic thinking when the teachers describing sustainable development and technology, as connected to technological systems with the aim to understand something as whole. Humans are also mentioned in the excerpt which we see as a more nuanced and complex way of understanding the relationship between technology and sustainability then in category A and B

"Teaching about sustainable development must be conducted in connection to technological systems, since learning about sustainable development must include entities. If you study the production process, one needs to look at the whole process and the systems that are included or affected by this production process. This includes looking at where the raw materials come from and how the working and living conditions are for those who work with raw material. Sustainable development will be almost automatically a part of teaching technological systems, if it is to become genuinely understanding."

What is significant in this category is that technological systems are mentioned and that a more holistic way of describing the relationship between technology and sustainability come into sight.

Discussion

The results indicate that the responding technology teachers' in the Swedish compulsory school believe that sustainable development is closely connected to technology and technology education. They describe an understanding of technology and sustainable development as systemic.

The results also indicate that teachers in our pilot study, to some extent, uses a systemic approach when describing the relationship between technology education and ESD. The approach is more notably in category C, where parts and wholes are centrally described in connection with the teaching of technology and sustainable development. In category B and C we interpret a relation to a system approach when teachers describe that technology affects the nature and society and emphasizes this as natural interconnection of education in technology and sustainable development. However, we find a narrow connection to a system approach in the results, but due to the limited number of participants in the study and the fact that the open-ended questionnaire may not invited participants to develop their response sufficiently, it is not possible to draw general conclusions before more substantial data has been collected. We, thus believe that a systemic approach can be a driving force in connecting these areas and develop teachers' perceptions of the relation between technology education and ESD further.

References

Ben-zvi-Assarf, O., & Orion, N. (2005). A study of junior high students' perceptions of the water cycle. *Journal of Geoscience Education*, *53*(4), 366.

Churchman, C. W., & Churchman, C. W. (1968). *Challenge to reason* (pp. 383-93). New York: McGraw-Hill.

Elshof, L. (2009). Toward sustainable practices in technology education. *International Journal of Technology and Design Education*, *19*(2), 133-147.

Jucker, R., & Mathar, R. (2015). Introduction: From a Single Project to a Systemic Approach to Sustainability—An Overview of Developments in Europe. In *Schooling for Sustainable Development in Europe* (pp. 3-14). Springer International Publishing.

Kamp, L. (2006). Engineering education in sustainable development at Delft University of Technology. *Journal of Cleaner Production*, *14*(9), 928-931.

Koski, M. I., & de Vries, M. (2013). An exploratory study on how primary pupils approach systems. *International Journal of Technology and Design Education*,*23*(4), 835-848.

Leal Filho, W., Manolas, E., & Pace, P. (2009). ESD: current discourses and practices and their relevance to technology education. *International Journal of Technology and Design Education*, *19*(2), 149-165.

Örtnäs, A. (2007). *Elevers vardagsuppfattningar om tekniska system*. [Pupils' everday conceptions of technological systems] Bachelor's Thesis/examensarbete. Linköping University. Linköping.

Pavlova, M. (2013). Teaching and learning for sustainable development: ESD research in technology education. *International Journal of Technology and Design Education*, *23*(3), 733-748.

Pitt, J., & Lubben, F. (2009). The social agenda of ESD within design & technology: the case of the Sustainable Design Award. *International Journal of Technology and Design Education*, *19*(2), 167-186.

Senge, P. (1990). The fifth discipline: The art and science of the learning organization. *New York: Currency Doubleday*.

Skolverket. (2011). Läroplan för grundskolan, förskoleklassen och fritidshemmet 2011 [*Curriculum for the compulsory school 2011*]. Stockholm: Skolverket.

Stables, K. (2009). Educating for environmental sustainability and educating for creativity: actively compatible or missed opportunities?. *International Journal of Technology and Design Education*, *19*(2), 199-219.

Svensson, M. & Ingerman, Å. (2010). Discerning technological systems related to everyday objects – mapping the variation in pupils' experience, *International Journal of Technology and Design Education,* 20(3), 255-275.

Svensson, M. (2011). *Att urskilja tekniska system: didaktiska dimensioner i grundskolan*. [Discerning technological systems: pedagogcial possibilites in compulsory school] Studies in Science and Technology Education 33, Linköpings universtiet.

UNESCO (2009). Review of Contexts and Structures for ESD. http://unesdoc.unesco.org/images/0018/001849/184944e.pdf (accessed on May 10, 2015)

Wals, A. E., & Kieft, G. (2010). ESD. *Research Overview*, *13*.

European Results of the Future of Technology and Engineering Education Study

N.H. Toemen
M.J. de Vries
Delft University of Technology, the Netherlands
m.j.devries@tudelft.nl

Summary

This paper presents the European results of the future of Technology and Engineering Education study. For this explorative study a survey was distributed among 20 PhD students within the technology education field. There is no clear consensus between the panellists. However, a descriptive analysis shows a couple of results: (1) content focus technological literacy should be integrated with design technology and STEM. (2) The instructional strategy should be project- and design-based, focussing on the context of technology. The future of the subject will be very similar to the current state of technology education (3).

Introduction

This paper presents the European results of a global study. The goal of this study is to determine the perspectives of new PhD graduates (or those close to graduating) who have specialized in the field of K-12 (primary and secondary education) technology, engineering education, aiming towards the future of this teaching subject area. New graduates might progress to become leaders of their profession. The researchers seek to determine the directions which these graduates might pursue with their content of their subject areas, methods of teacher education, planned professional involvement and other future developments in this field.

For this explorative study a questionnaire was send to PhD various European students involved in the research of technology and engineering education.

Relevance

Research about Technology and Engineering Education (T&EE) involves numerous aspects of the topic (Martin and Ritz, 2012, Ritz and Martin, 2012).

In their study Martin and Ritz studied the needs for further T&EE research, as perceived by their 17 U.S.-based respondents (Martin and Ritz, 2012). By focussing on two areas; issues related to T&EE in general and the preparations for teaching T&EE. In their findings seven research directions are suggested: (1) engineering content and curriculum, (2) impact on academic achievement, (3) verification of content, (4) benefits of K-12 T&EE, (5) shortage of critical research, (6) student learning and (7) cognitive science connection. The fourth topic was perceived by the panel as most important, with a mean of 4.24 out of 5, as it is fundamental for the future and the continued existence of T&EE. However, involving research and/or development activities, the topics about the T&EE curriculum and content were valued higher by the panel. Resulting in a list of future research topics in the presented order. Taken into account this is still an U.S. perspective. After repeating this study on research criteria - on an international level, with 32 participants - different topics were selected (Ritz and Martin, 2012). The differences might be due to a highly varied descriptions of the research fields. A few of them are also related to the development of the curriculum and the development of educators.

These results taken into account, people involved in the field of T&EE require some guidance in the development of this school subject. In addition, the large number of people involved in the decision making process surrounding T&EE (Rasinen, 2011) require a proactive attitude from the

field itself. Since policy makers might have different objectives. The goal of this study is to make T&EE future proof.

Theoretical framework

This study identified the future role of the current European PhD students in the field of technology education and their perspectives on the matter. A perspective on technology education by leading academics on this topic is also provided in the work; The Future of Technology Education (Williams et al., 2015). Williams et al. introduce a model that represents aspects of technology education (nature of technology, curriculum, pedagogy and students cultural capital) and explore the current state of T&EE and in what way it stays relevant in the future.

Considering the technology curriculum, Barlex present the arguments for technology education, three procedural principles that could/need to be taken into account while developing the curriculum and the relationships with other school subjects (Barlex, 2015). Each argument in favour for T&EE (economic, utility, democratic and cultural) will affect the content of the curriculum. An economic argument - a supply of technologically skilled labour - will focus on the workforce. The utility argument focuses on design- and problem solving skills, the democratic and the cultural arguments on technological literacy. Just like arts and literature is technology part of a culture. In developing a technology curriculum, Barlex proposes three procedural principles which would suggest the focus of the curriculum. The reasons for technology education can be translated into the following principles:
- being true to the nature of technology,
- developing a perspective on technology
- enabling students' technological capability.

Developing a perspective on technology is based on the (social) context of technology. Evaluating or forecasting the implications of a disruptive technology will contribute to a students' perspective on technology. Which in turn will contribute to decision making about, or the valuing of technology (in line with the democratic argument).

Technology education had the potential to be involved in other school subjects, since a relationship can be mutually beneficial. Most common are the S, E and M of STEM. As Barlex indicates, the relationships between the subjects need to be equal. In practice, technology within STEM is degraded into applied sciences, and with this not giving the full potential of technology education. When designing in part of the technology curriculum collaboration with arts, turning STEM into STEAM, is also an valuable option. Both STEM and STEAM are part of national policy in promoting technology integration in school curricula (Buntting and Jones, 2015). Like Baxler, Buntting and Jones address the options in integrating technology in STEM or other school subjects. Nevertheless, they emphasize the importance of a clear distinction between technology and the sciences. The nature of technology and the difference with the nature of science needs to be clear for teacher and in turn to the student. As an equal collaboration within STEM is seen as a likely future, Buntting and Jones suggest a further integration of school subjects. One of the proposals is the iSTEM-pedagogy, using math, science and engineering concepts in designing, recreating and evaluating problems. A further step will be a shift in the educational paradigm (the way secondary schools are operated), to enable a type of education that provide students with (group) projects, which are context-based, and involve more than one school subject. This type of education will address the so-called 'twenty-first century learning needs' of their student. Within this framework, the results will be evaluated.

As this section suggested, are there numerous options and possible directions T&EE could develop into. No direction is preferred, but a combination of knowledge and skills is. The decision, of which direction to pursue, needs to be taken by policy makers, but most importantly class teachers whom will implement the curriculum. The perspectives of the teacher educators will be of great influence in this decisions. This is the focus of this research. Trying to identify the possible direction of European (or national) T&EE.

Research design

Next to the perspective of leading academics, the perspective of potential future leaders in the T&EE field is important. PhD graduates (or those close to graduating) are assumed to be these future leaders. By their (future) research and involvement in (inter) national networks they will influence the education of classroom teachers and the content of the curriculum. Identifying their future role and contribution and determining the direction that these graduates might pursue with their subjects area's content, methods of future teacher preparation, planes professional involvement and future forecasting for this school subject a perspective of the T&EE future will be established. Therefore the following research questions are derived:

RQ1: What are new PhD graduates' opinions concerning the focus of content to be learned in K-12 technology and engineering education.

RQ2: How do new PhD's believe technology and engineering teachers will be prepared in the near future?

RQ3: What is the commitment level of new PhDs to their technology and engineering teaching profession?

RQ4: What do new PhD's expect to occur in the future to the technology and engineering teaching profession?

Based on the study's proposed research objectives, the initiators of the U.S. study designed an electronic questionnaire. This questionnaire was distributed to the European respondents as well. The literature suggested topics of importance to the future of a K-12 teaching profession. This information was used to develop the questions for this survey. Since this is an explorative study this survey will have numerous multiple answer questions. The survey was distributed to volunteers via Survey Monkey. This service collects data anonymously form participants.

The questionnaire consisted of three parts. The first part concerned the present with topics as: content of the T&EE education, instructional strategies, primary audience and journal subscriptions. Secondly, questions concerning the year 2025: teacher preparation and development, relevant journals and associations and involvement. Third, general information about the respondent: gender, age, current position and country of residence. All topics are derived from research and writing within the T&EE field.

In identifying the future content is preselected: technological literacy (ITEA, 2000), workforce education, engineering design and STEM integration (Gibson and Bell, 2011). There are a couple of different instructional strategies that reoccur in literature; project-based (Shome et al., 2011), design-based (Hansen, 2009, Shome et al., 2011, Gómez et al., 2012) and concept/context based (Hennessy and Murphy, 1999). Both topics, content and instructional strategy, multiple answers were possible, as well as the possibility of specifying an "other" option.

Sample and procedure of data collection

Europe counts ten universities who offer a PhD position in T&EE: Sweden, France (two institutes), the Netherlands, Belgium, Germany, Switzerland, Norway, Finland and the UK. The electronic survey was distributed by the researchers to nine lead professors in each country. These professors where asked to distribute the survey to their PhD students. Participation in this study was voluntary. Since all data was collected anonymously there was a minimal risk in participation in this study. Aside from the study outcome, participating in this study had no direct benefit. Data was collected in January and February 2014 and resulted in 20 cases. The respondents have their PhD in Sweden (9), Finland (3), the Netherlands (2), United Kingdom (4), Belgium (1) and Germany (1). The ages of the respondents were 20-30 (1), 31-40 (11), 41-50 (3) and 51-60 (5).

The sample of 20 cases might seem very small. However, considering the limited number of European institutes that offer such a PhD program and the limited positions at these institutes, the number of European PhD students within technology education, is estimated at 40. Since the researchers are familiar with and actively involved in this European T&EE PhD network, this sample is considered to be representative for the whole group.

Results

Due to the small sample size, the analysis is limited to descriptive- and correlation analyses. Obviously, none of the correlations could be considered significant.

Content, instructional strategy and primary public

Concerning the focus on the content, all respondents indicated Technological Literacy as important. However, the majority of the respondents indicated technological literacy as a part of the curriculum in combination with other topics (70% of all the respondents). However, there is no clear consensus of the preferred combination (table 1): with STEM integration (15%), or design technology (10%), or both workforce education and design technology (15%), design technology and STEM integration (10%) and 10% of the respondents perceived no focus on any of the topics, they indicate a combination of all four topics as desirable. Or as a respondent remarked: T&EE needs to be *"interdisciplinary beyond STEM as well."*

Linking these answers to the country of residence of the respondents a more interesting image arises. Both respondents from the Netherlands expect Design Technology as important, whereas the majority of the respondents from Sweden and Finland expect the opposite. About half of the Swedish respondents expect a sole focus on technological literacy sufficient. The UK based respondents have a larger interest in STEM Integration and Design Technology than other respondents. The fact that the UK respondents are more likely to address these two topics is not strange, considering the focus of national policy on STEM education in previous years and the long history of design. A weak correlation is found between the focus on Design and the respondents' location (r=.355), suggesting the importance of design is slightly related to the country of residence.

Table 20 The focus of the T&EE content by respondents' country of residence

Frequency	Percentage of total	Focus of content	Country of residence
6	30.0	Technological literacy	1/1 Belgium, 1/3 Finland, 4/9 Sweden
4	20.0	Technological literacy + Design Technology	2/9 Sweden, 2/4 UK
3	15.0	Technological literacy + STEM integration	2/9 Sweden, ¼ UK
3	15.0	Technological literacy + Workforce Education + Design Technology	1/3 Finland, 1/1 Germany, ½ Netherlands
2	10.0	Technological literacy + Design Technology + STEM integration	1/9 Sweden, ½ Netherlands
2	10.0	Technological literacy + Workforce Education + Design Technology + STEM integration	1/3 Finland, ¼ UK

Considering the focus of instructional strategy a respondent remarked that this *"depends on too many things. This is not an either or question".* Almost all respondents supported this statement. The focus of instructional strategies is perceived as a combination of strategies too, as shown in table 2.

A project-based approach is preferred over a more classical education setting (non-project and non-design) by 75% of the respondents. Or as a respondent puts it: *"Hands on- brains on- inquiry based learning".* Design-based learning is considered a project-based activity, not an individual assignment (r=.577). The 25% suggesting a more classical instructional strategy are mainly from the Scandinavian respondents, which is supported by a moderate correlation between country of residence and a project-based instructional strategy (r=.510). Respondents do think that learning about technology is important with the context in mind (80%). Supporting the contextual approaches of Buntting and Jones and Barlex (Buntting and Jones, 2015, Barlex, 2015).

The relation between content and instructional strategy shows some more interesting insights. From the six respondents suggesting only adapting technological literacy in the curriculum three suggest a traditional classroom setting. These three graduates are all from Sweden. In light of this

it is worth mentioning that Swedish education is more focussed on social and societal factors, compared to the other countries within this sample. These results are representing the current state of Swedish technology education.

As stated the strategy of designing-based and project-based learning were related to each other. However design technology as content is very weak correlated to the design- (r=.101) or project-based learning (r=.174). Of the 11 selected, 9 suggest a project assignment. Just 6 respondents, indicating design to be part of the content, suggest a design activity. For five respondents this would result in learning about design without actually designing.

Table 21 instructional strategies by respondents' country of residence

Total N=20	Non-project and non-design (25%)	Project based (25%)	Project + Design based (50%)
	-	1 (5%) Finland	1 (5%) Finland
Contextual learning (30%)	2 (10%) Sweden	3 (15%) Sweden, Germany & UK	1 (5%) Sweden
Conceptual learning (10%)	2 (10%) Sweden	-	-
Contextual + conceptual learning (50%)	1 (5%) Sweden	1 (5%) UK	8 (40%) Belgium, Finland, Netherlands, Sweden & UK

The age of the students that is considered suitable for learning about technology is primarily when the students are in secondary education (high- or middle school), the age of 10-18, since this age group is represented in all the responses. Suggesting that Technology education is primarily a secondary students' thing. In contradiction to this is the large group that also suggest T&EE for primary education. Noteworthy is, those who consider technology appropriate for all ages are mainly from the Netherlands and UK. The Scandinavian respondents mainly indicate the middle school and up (from age 11) as the primary audience (table 3). These results could be seen in light with the current state of the national technology education. For example, the current Finnish T&EE curriculum is considered heavy; a lot of topics, theoretical and is an integral part of the secondary education. This program, as it is now, might not suit younger children.

When relating the primary audience to the suggested content, selecting the all ages group 66% suggest design as part of the curriculum. When selecting the other cases this amount is slightly less, 50%. Suggesting design as content is appropriate for elementary students. In relating the audience to the instructional strategy, designing is not more suggested in the "all ages" group (44%) compared to the secondary education group (50%). However all respondents indicate for the group including elementary students a project-based approach.

Table 22 Primary T&EE audience by respondents' country of residence

		Primary audience				Total
		Middle grades students (age 10-14)	High school students (age 14-18)	Secondary students (age 10-18)	All (age 5-18)	
Country of residence	Sweden	1	4	1	2	8
	Finland	1	1	0	1	3
	Germany	0	0	0	1	1
	Belgium	0	1	0	0	1
	Netherlands	0	0	0	2	2
	UK	0	0	1	3	4
Total valid		2	6	2	9	19

The future of educating technology educators

The perspective on the way technological educators needs to be trained in 2025 is not very different as current practices. The results, however, suggest more collaboration between professionals within the field of technology and school education. Professionals awarded with a degree in a certain discipline, which become teachers (favoured by 35% of the respondents) or professionals from the university (favoured by 40%, table 4). What is remarkable in table 4 is the preference of the Finish. All respondents from Finland indicate a 4- or 5-year program. In Finland the current training is a 5-year master program.

Through which channel these professionals acquire their licence is less clear. 85% indicates that a hybrid system that involve blended methods of instructional delivery (campus and distance learning) as sufficient. As a respondent states a "hybrid system including some time spend in the real world i.e. with some practice in classrooms with kids". The other 15% indicate a combination of a brick and mortar university and in school education. This suggests a strong perceived benefit of the traditional educations methods for educators. Even when the respondents suggest receiving a qualification through distance learning technologies, teacher education institutions should provide these. What kind of service providers should facilitate the hybrid system is not very clear, considering no correlation is found between the hybrid system variable and the service provider variables, as shown in table 5.

Table 23 Educator preparation by respondents' country of residence.

		Primary characteristics classroom teachers			Total
		4- or 5-year campus-based program	Discipline degree followed by teaching diploma	Combination university – school based	
Country of Residence	Sweden	1	4	4	9
	Finland	3	0	0	3
	Germany	0	0	1	1
	Belgium	1	0	0	1
	Netherlands	0	2	0	2
	UK	0	1	3	4
Total		5	7	8	20

Table 24 Correlation between a hybrid system of preparation and proposed service providers

		National supervisors	Commercial vendors	Professional associations	Teacher education institutes	Distance learning providers
Hybrid system	Pearson Correlation	-.183	.140	.140	-.275	-.081
	Sig. (2-tailed)	.440	.556	.556	.241	.735
	N	20	20	20	20	20

Future role of PhD's

The future role of the PhD's will be an active role. When asked about the subscriptions to technology education journals, 13 respondents label themselves as a regular reader. These PhD students will be frequent attendees of conferences. One respondent expect to visit almost all of the suggested conferences, remarking: *"I believe in conferences where teacher and researcher meet and share experiences".* Perceived relevant conferences are the US-based ITEEA (55%), the Netherlands based PATT (50%) and the Australian TERC (40%). Also national conferences will be attended. Almost all respondents indicate they expect themselves to stay actively involved and contributing to T&EE organisations (80%), with multiple activities. This involvement is illustrated by some remarks:

"hopefully publications in journals, education work for teachers from Tech.edu, national work developing technology education (also international if possible)".

"Science centre development. Research in school setting. School development programs. Networking with stakeholders such as politicians, parents and technology companies".

"Through research and curriculum development/leadership in technology education."

"Organizing arenas for people to meet and share experience regarding enhancing student learning".

"One part of my work as technology education teacher is to develop TE, so I find it important to take part to professional organization".

"I am currently involved with the D&T Association as a member of a working group and have become involved with groups having input on the National Curriculum (England) for 2014 - including Education for Engineering event and the D&T Expert Group. My ambition is to remain in Higher Education and Influence Design and Technology Education, with the aim of moving on to a reader/professorial role by 2025."

 "Teacher, trainer, researcher and producer of educational resources".

When indicating that by 2025 the respondents will no longer be actively involved it is due to their age (51-60) years old. Or as one of them clearly stated: *"I will probably be retired".*

The perceived future of technology education

It is perceive that, by 2025 T&EE will be similar to what is looks like today (50%) or it is integrated within STEM (40%). Within the countries are the perspectives different and the correlation between the future of education and the countries weak (r=-0.43).

Table 25 Perceived future of T&EE

	Frequency	Country of residence
Similar	10	3 Sweden, 2 Finland, 1 Germany, 1 Netherlands, 2 UK
Integrated in STEM	8	4 Sweden, 1 Finland, 1 Belgium, 2 UK
Integrated in science	1	Netherlands
Disappear	1	Sweden
Total	20	

Conclusions

RQ1: *What are new PhD graduates' opinions concerning the focus of content to be learned in K-12 technology and engineering education.*

In line with the perspective of Baxler and Buntting and Jones (Barlex, 2015, Buntting and Jones, 2015) the PhD graduates suggest a focus on the nature of technology, as covered in Technology literacy. Combining the different aspects of technology is suggested in both literature and the results of this research. Which combination this should be is dependent on national policy of that country. In addition, the technological skills (Barlex, 2015) is perceived important. Implementing designing in the curriculum will contribute to these capabilities.

Corresponding with the view of the lead academics (Williams et al., 2015) the respondents indicate the importance of the context of technology and the multidisciplinary nature of it. Through (group) projects and integration with STEM will shown that technology is not a one-man show.

RQ2: *How do new PhD's believe technology and engineering teachers will be prepared in the near future?*

The future technology classroom teacher will be educated through a system in which take part: universities, schools, teacher education institutes and professional associations. By taking classes on or off campus, practicing in an actual school setting is still perceived important. The results concerning this topic suggest more integration between T&EE and actual, real life technology practice. The future T&EE teacher is not just a T&EE teacher. He or she will have a specific discipline or even some experience as working within the technology field.

Next to that, reading journals, writing about the profession and attending conferences will be important for the future leaders in T&EE. These activities might also be important for classroom teachers as well. Exchanging thoughts about the subject, between researchers, teacher educators, classroom teachers and professionals, will continuously improvements and research about

technology education. Since these conferences will cover educational research within T&EE and translates it into practice.

RQ3: *What is the commitment level of new PhDs to their technology and engineering teaching profession?*

With the majority of the PhD graduates in the age of 31 to 40 year, this is a group with a lot of potential in being involved in this profession. The results indicate a high level of involvement and commitment to the T&EE profession. Indicated by the current number of subscriptions of T&EE journals and future activities. The main activities will be publishing, teaching at (secondary schools) and also educating teachers. Other contributions will be developing a science centre, organising events, researching technology education, school program/curriculum development, lobbying and networking.

However when the age increases the involvement will decrees. Of all 51+ respondents almost all expect not to be involved in the future.

RQ4: *What do new PhDs expect to occur in the future to the technology and engineering teaching profession?*

The technology education will not be of influence of major change, as the PhDs suggest. Which would suggest that the future teacher will need a similar skill set as the present-day teachers. Which, in turn, means that the future technology teacher will need to be able to manage project-based education processes. In addition the future technology teacher need to have conceptual knowledge about technology and design, in order to teach technological literacy and design technology. Which is supported by literature (Barlex, 2015, Buntting and Jones, 2015), indicating that a technology teacher with actual technological knowledge is a necessity. In some cases the 'discipline degree followed by a teaching degree' is often a hands and crafts teacher turning into a technology teacher. Who might have a different perspective on technology as a 4-5 years educated technology teacher. They are probably more focussed on the ideas of technology (e.g. knowledge of materials) and technological skills (Barlex, 2015), which does not suggest anything about the quality of the T&EE lessons. However being explicit in the background and perspectives of the teacher is key in technological education.

Discussion and limitations

Where lead academics present five factors within technology education that need to be in line in order to establish future-proof technology education, 50% of the PhDs indicated no dramatic changes for technology education. This result could suggest two things. (1) The current state of technology education in the countries already has an alignment of the five factors, or (2) the PhDs were unable to forecast the future of technology education. In the majority of the responses represented the current situation of the technology education. This corresponds with the answers on how technology education will be in the future (Similar=50%). However this contradicts with the changing nature of technology. Although technology might change, the school subject would stay the same.

Politics seems to be of great influence on the results. In the responses national policy could be identified (e.g. UK and Finland). Which does not come as a surprise (Williams et al., 2015). Therefore it is more likely that the results show the current state instead of a future state of the field. When the political climate shifts, perspectives on technology education might shift as well.

8 References

BARLEX, D. 2015. Developing a Technology Curriculum. *In:* WILLIAMS, P. J., JONES, A. & BUNTTING, C. (eds.) *The Future of Technology Education.* Singapore: Springer.

BUNTTING, C. & JONES, A. 2015. The Alignement of Technology with Other School Subjects. *In:* WILLIAMS, P. J., JONES, A. & BUNTTING, C. (eds.) *The Future of Technology Education.* Singapore: Springe.

GIBSON, K. S. & BELL, I. 2011. When Technology and Design is Inhabited by Mathmatics. *International Journal of Technology and Design Education,* 16**,** 28-39.

GÓMEZ, S. M., VAN EIJCK, M. & JOCHEMS, W. 2012. A sampled literature review of design-based learning approaches: a search for key characteristics. *international journal of technology and design education,* 23**,** 717-732.

HANSEN, P. J. K. 2009. Analysing cases in Technology and Design Education: How Could Designing and making technological products be a vehicle for enhancing understanding of natural science principles? *Design and Technology Education: An international Journal,* 14**,** 45-52.

HENNESSY, S. & MURPHY, P. 1999. The Potential for Collaborative Problem Solving in Design and Technology. *International Journal of Technology and Design Education,* 9**,** 1-36.

ITEA 2000. Standars for Technological Literacy: Contant for the Study of Technology Reston: Internation

MARTIN, G. & RITZ, J. 2012. Research needs for technologycal education: a U.S. perspective. *Journal of Technology Education,* 23**,** 25-43.

RASINEN, A. What determines technology education in schools? Tradition, educational research, politics, education administrators, teachers, or . . .? *In:* STABLES, K., BENSON, C. & DE VRIES, M., eds. PATT 25: Cript 8, 2011 London. Goldsmiths, University of London, 340-347.

RITZ, J. & MARTIN, G. 2012. research needs for technology eduction: an international perspective. *International Journal of Technology and Design Education,* 16**,** 767-783.

SHOME, S., SHASTRI, V., KHUNYAKARI, R. & NATARAJAN, C. What do students learn from designing and making a playground model? *In:* STABLES, K., BENSON, C. & DE VRIES, M., eds. PATT 25: Cript 8, 2011 London. Goldsmiths, University of London, 357-366.

WILLIAMS, P. J., JONES, A. & BUNTTING, C. 2015. *The Future of Technology Education,* Singapore, Springer.

Technology teacher's use of a CoRe to develop their PCK

P John Williams, Curtin University, Australia
pjohn.williams@curtin.edu.au
John Lockley, University of Waikato, New Zealand
jlockley@waikato.ac.nz
Jenny Mangan, University of Waikato, New Zealand.
jenny.mangan25@gmail.com

Abstract

The majority of research that has been conducted about the use of Content Representations (CoRes) as a way to articulate teachers' Pedagogical Content Knowledge (PCK) has been with science teachers. Recent research has provided some indication that the CoRe structure may not suit the nature of technological knowledge and the way technology teachers think. This presentation will report on a research project in which technology teachers developed and implemented a CoRe, and together with the researchers, evaluated its applicability to the technology education context.

Key words: PCK, CoRe, Technology education, technological knowledge

Introduction

There is now a significant body of research related to teacher Pedagogical Content Knowledge. The notion was first elaborated by Shulman (1987) as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learning, and presented for instruction" (p. 8). Shulman (1987) proposed a number of domains or categories to deal with the complexity of the knowledge base that experienced (good) teachers draw upon:

- Content knowledge;
- General pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter;
- Curriculum knowledge, with particular grasp of the materials and programs that serve as 'tools of the trade' for teachers;
- Pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their special form of professional understanding;
- Knowledge of learners and their characteristics;
- Knowledge of educational contexts, ranging from workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures; and
- Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds.

Nature of a CoRe

In 2006, Loughran et al developed what they termed Content Representations (CoRes) as a way of representing teachers' PCK. CoRes, as represented in Table 1, attempt to portray holistic overviews of expert teachers' PCK related to the teaching of a particular topic. They contain a set of key ideas, and a set of pedagogical questions/prompts which interrogate each key idea.

Table 1. *Sample Content Representation (CoRe) matrix.*

Pedagogical Questions	Big Idea 1	Big Idea 2	Big Idea 3
What you intend the students to learn about this idea?			
Why is it important for the students to know this?			
What else you know about this idea (that you do not intend students to know yet)?			
Difficulties connected with teaching this idea (limitations)			
Knowledge about student thinking which influences teaching about this idea			
Other factors that influence your teaching of this idea			
Teaching procedures (and particular reasons for using these to engage with this idea)			
Ways of ascertaining student understanding or confusion about the idea			

Research in technology education reveals a limited understanding of the role of PCK, although an international discourse does exist with studies being reported in both general design and technology education (De Miranda 2008; Jones and Moreland 2004; Rohaan, Taconis, and Jochems 2009, 2010), STEM (Hynes, 2012; Love, 2015) as well as in different disciplines of technology such as information and communication technology (Koehler and Mishra 2005). While researchers like McCormack (1997, 2004), Compton (2004) and Williams (2012) identified the interrelated nature of procedural and technical knowledge in technology education, international diversity remains a characteristic of the content of the technology domain, which is an impediment to the consistent development of PCK in the area of technology education.

Studies by Williams et al. (2012) and Williams and Lockley (2012) aimed to research the use of a CoRe as a planning tool to develop early career secondary teachers' PCK and were designed to examine whether such a tool, co-designed by an early career teacher, together with expert content and pedagogy specialists, can enhance the PCK of the early career science and technology secondary teachers. A research design was developed that incorporated a unique partnership between an expert classroom teacher, an expert in subject matter knowledge (e.g., scientist or technologist), an early career teacher and an experienced researcher who had previously conducted research in each subject. Two four-member partnerships were formed, one in science and one in technology. As the research progressed and the data were analysed, it became clear that the science group and the technology group reacted with the CoRe proforma in different ways. For example:

1. There was a marked difference between the way the science group and the technology group approached their first workshop task of developing the key ideas. The science group much more quickly developed a consensus about the key ideas because they already had in mind a common idea of what was important for this topic. In the technology group, there was a sense of developing the list of key ideas from first principles; consequently, there was far more negotiation and justification in the workshop leading to the development of agreed

ideas. There was no schema that was familiar to all the technology workshop participants that could provide a common starting point.

2. The immediate usefulness of the CoRe seemed to lie in different areas for technology and science. The science teachers seemed to get the most benefit from seeing the need for, and developing with confidence, examples of organic chemistry in authentic contexts to support students' theoretical understandings. The technology teachers saw the immediate benefit in quite the opposite way. For them the opportunity to see the big picture of Materials Technology, to articulate its theoretical underpinnings and consequent development of a philosophy that was conducive to a rational epistemology, was perceived to be the main benefit.

3. The application of the CoRe to a teaching unit was different in science and technology. In science, the chemistry CoRe was truly a content representation, dealing with a discrete and contained unit of work that was treated as such by textbooks. In technology, where procedural knowledge was highly valued, the Materials Technology CoRe had to be contextualized within a project, which permitted the application of the content. So it was not a self-contained content representation, but rather a topic that could be applied within a project context.

4. The practical/theoretical dichotomy was an aspect of both the science and technology teachers' implementation of the CoRe, but in opposing ways. The science teachers noted that after an examination and discussion of the pedagogical questions related to the content ideas in particular, they had a deeper understanding of the importance of engaging in practical activities in order to assist students' understanding of the relevance of the topic. The reverse was the case for the technology teachers. After realisating the need for a conceptual framework prior to determining the key ideas for the topic during the first workshop, the teachers felt that students also needed a broader framework of understanding than their immediate and felt needs related to the completion of their current project.

The concept of the content area or topic that a CoRe refers to is relatively unproblematic in Science. Science has a well-established epistemology, leading to an established organisation of knowledge into accepted topics of inquiry. Technology on the other hand has a shorter history of study as a philosophical enterprise and no commonly agreed upon epistemology. Robust debate still exists about the nature of knowledge in technology and the way knowledge empowers technological practice (Compton & Harwood, 2003; Rauscher, 2010)

In the context of a CoRe, the differences between the nature of technological and scientific knowledge have not been thoroughly researched. Relevant technological knowledge is defined by its usefulness to the task at hand. If it does not help to achieve a specific goal, then it is neither useful nor relevant. Consequently, it is difficult to predetermine what technological knowledge is relevant because problems that may arise in the pursuit of a technological goal cannot be anticipated. So the notion of designing a CoRe in the current format and using that as the basis for the design and implementation of a unit of work in technology is fraught.

Research project

An action research project was devised in which the researchers worked with the research participants to investigate the use of CoRes in technology education. All the research team were involved in the action research process steps of selecting the focus of the research, examining the

literature, identifying the research questions, collecting and analysing the data and then taking action (Sagor, 2000). The participant researchers were three teachers who were recognised as being expert classroom practitioners in technology education, and were selected on the basis of their Head of Department recommendation.

The action research spanned six months over two school terms. The first two phases involved planning the CoRes, during which the teachers reflected on the usefulness of the traditional CoRe design when applied in technology education, and collaboratively designed/redesigned CoRes for application in their classroom teaching. Then the teachers implemented the CoRe in their classroom, and in the final phase all the research participants came together to evaluate the effectiveness of the CoRe design, analyse the data and develop a revised CoRe design, and plan for further action.

Data collection was through teachers' CoRe worksheets, researcher observations of classrooms, and recordings of interviews and workshop discussions. This presentation is of the initial findings, and is based only on the recorded interview data.

Data Analysis

For this research an interpretive research paradigm was adopted, based on the belief that knowledge is constructed within a social and cultural setting of relationships between people. This aligned with the sociocultural theoretical framework (Wertsch, 1998) which underpinned the inquiry and data analysis, and helped to describe and theorise the complex challenges involved in using action research as an approach to improve PCK through CoRe development.

The qualitative data collected from the classroom observations, interviews and workshop discussions were subjected to thematic analysis, which was initially deductive, then progressively inductive. As the data were coded, themes were developed, which were then reviewed, defined and named (Braun & Clarke, 2006), ensuring that they were both as exhaustive and as mutually exclusive as possible – this helped to ensure the content validity of the narrative (Cohen, et al., 2011).

Findings

The process of CoRe Construction

Workshop 1 involved the development of an understanding of PCK and CoRes. The CoRe was presented as having been developed in the context of science, and in the application to technology in this project, there was no presumption that the questions were valid or useful. It was recognized that the science questions were all about knowing, whereas in technology, it is the application of the knowledge in terms of both understandings and abilities. It involves an integration of applied knowledge and ability – they integrally inform each other.

Part of the task in the initial workshop was to deconstruct a teaching sequence for each teacher back into a CoRe structure. So each teacher thought of an activity or task they had done recently with a class, and as a group, the teachers and researchers interrogated each teacher in turn to identify the 'Big Ideas' and then answer the 8 core questions for each idea. This provided the opportunity for teachers to ask questions and develop a deeper understanding of the nature of the Core.

Very early on in the discussion it was clear there was discontent with the notion of Big Ideas, particularly in some contexts. For example in the upper secondary years when each individual student will find their own problem, and then design and make a solution to that problem – the content that students need in order to make informed design decisions will be different in every case.

Based on the understanding developed from the first workshop, in the period before the second workshop, the teachers spent time planning and considering the focus of the technology activity

they would use to implement the CoRe, which would be constructed in a group during the second workshop.

The second workshop began with specific planning for the trial of the CoRe in the following school term. The teachers each discussed the context they were going to use. One was titled 'Heat and Eat' in which students were to create a dish suitable to freeze and reheat. The plan was to work with Muscle Fuel (a meal preparation company for body builders). Students will choose an athlete, and then design a meal to suit their particular nutritional needs. Another teacher's project was 'Trick bikes', a year-long project in which this segment would focus on the back axle assembly, deciding on materials, their structure and properties that match the desired performance.

The group then brainstormed the chronological sequence of activities the teacher would go through with their students and together filled out a CoRe on the whiteboard. In going through the structure of the CoRe, each of the teachers were interrogated by the other 5 researchers.

Using the CoRe

The participants finished completing their CoRes independently after the workshop. When they started teaching the section of work they were already positive about the benefits. Using the CoRe forced them to think more critically about their teaching. This resulted in more thorough planning and they felt better prepared, which impacted on their pedagogy. LM admitted that previously he just relied on his experience rather than considering all the details: "So you're doing things, and because you've done it before, and you've gone through that process, so you just go and do it. But this [the CoRe] actually really clarified it in my mind".

All the teachers felt challenged by the question: *Why is this important*? It appeared to stimulate significant critical reflection and helped them identify key concepts. LK admitted: "I have never really stopped and thought about why they need to know that. Is it actually that important? And, is there something else I could put in place of that? Or, is this the core element that they should know?" Clarifying her own understanding gave her more confidence and helped her to communicate the purpose of the learning to her students, which she felt improved student engagement. KD also found it helped her retain focus on key concepts, particularly during practical sessions where students tended to focus on 'cooking' rather than underpinning concepts, such as the technology process. It also prompted her to think about progression of learning, and preparing students to be more independent at senior level.

Considering the CoRe questions about students' prior learning and 'limitations' connected with teaching particular concepts and skills, assisted the teachers to identify the need to differentiate their teaching more. For example, LK changed her approach to a skills development lesson on inserting an invisible zip. Rather than demonstrate to the whole class she split them into two ability groups, which enabled her to better support students' varying needs. Similarly, KD found that identifying the varying levels of students' literacy and numeracy encouraged her to provide more scaffolding to support student achievement at different levels.

Another significant change stemmed from considering: *What deliberate teaching procedures are used?* LK noticed after completing several columns that she was writing the same teaching approaches each time. This made her realise that she needed to vary her pedagogy more to make it more engaging for students.

Both novice and experienced teachers found value in using the CoRe and the evidence suggests that they all enhanced their PCK to some degree. As a beginning teacher, KD felt that the CoRe provided a valuable scaffold for her planning. Despite many more years of experience, LM also found using the CoRe improved his teaching and he felt re energised by the experience.

There were a range of other documents to which, in order to be useful, the CoRe needed to relate, such as Unit Plans, Departmental strategies, Indicators of Progression, Key Competencies and Achievement Standards. While they had to consider these documents in their planning, the teachers felt that the CoRe was a way of bringing them together in a holistic manner.

The effect of the CoRe

Using a CoRe to plan for student learning had the effect of clarifying the teachers' understanding of what they wanted their students to learn. In technology, where the teachers argued there were so many skills and focuses to deal with at once, they felt it had an impact on their planning, giving more purpose and understanding to what they wanted to get out of the projects. The CoRe helped them think critically about the reasons for what they were teaching. It focused their planning on the technological process as opposed to the issues of the teaching context. Furthermore, completing the CoRe prompted teachers to consider whether what they had planned to teach was actually necessary, prompting questions such as: 'Is this something I could put aside and come back to later, or is it something I have to do because it is going to be the difference between them passing and failing?' This clarity of understanding of their educative purpose increased the teachers' confidence.

The CoRe gave the teachers a way to assess their own knowledge of what they wanted to teach helping them to identify gaps in their knowledge leading to them being better prepared. They also found the CoRe gave them a way to continuously reflect upon the intended student learning throughout the unit:

Until you actually sit and write it down, and fill it out and think 'oh, there are all sorts of gaps in there. Am I actually doing this the best way I could be doing it?

The teachers' increased clarity, purpose and confidence when using the CoRe affected their pedagogy. Using the CoRe prompted teachers to allow their students greater agency in decision making and the contextualization of their learning. For example LK talked about the differences to her approach using the CoRe. Previously she had controlled student learning by limiting the context of her students work to four styles of skirt. The CoRe had altered her thinking:

There are girls here that wouldn't even think of wearing a skirt. So this year we have eight different patterns. They are more interested in learning about how to sew a sample because it is going to be relevant for their next stage.

This greater agency and opportunity for students to contextualize their work in ways that were meaningful and authentic to them had the effect of increasing student engagement and enjoyment. The teachers reported their students working far more independently and engaged in their work with this in K's case leading to students talking about continuing with food technology the following year.

Use of the CoRe and its associated effects on teacher confidence and teaching clarity was for one teacher instrumental in improving his students' learning and achievement:

I have a student that I worked with last year. If I gave him this I would have got one page out of him. Now I have got 5 pages out of him …and he has covered … all these things. He has done more than just stated what it is. He has tried to explain things. I told management at the end of last year that there was no way I was going to be able to could get these guys through an achievement standard. Whereas now, I have pretty much got them all through".

Outcomes

The original CoRe category of 'Big Ideas' was seen as less appropriate for technology than for science. Much of the organization of teaching in technology is by project, and the teachers involved in this research were each using a project as the focus of their work with students. This then became the overarching organizer, as depicted in Table 4. Each project then has a number of Foci, a term considered more appropriate than 'Big Idea' (as in the original CoRe) because it may relate to the development of an ability or an understanding. Each focus then had a range of abilities or understandings which combined to make up the focus.

The PCK questions also consequently had to be changed to reflect the notion that they could be related to abilities and/or understandings. This change is also reflected in Table 4.

Table 4. *Technology Education Content Representations (TCoRes)*

PROJECT			
PCK Questions	**Focus 1**		**Focus 2 etc**
	ability/ understanding	ability/ understanding	ability/ understanding etc
What do you intend the students to learn?			
Why is it important for students to learn this?			
What abilities/understandings do students already have that this project can build on?			
What ability/understanding can be further developed as a result of this?			
What are the limitations connected with teaching this ability/understanding?			
What do you know about students learning and development which influences your teaching of this ability/understanding?			
What deliberate teaching procedures could you use to develop this ability/ understanding?			
How will you know students have developed this ability/understanding?			

As an example, the project in which LK selected to trial the CoRe development was termed 'Trick Bikes'. There were five consecutive and progressive Foci that the teacher had developed for this project which were:
1. Assemblies – back axle, seat and steering,
2. Component performance,
3. Material composition and properties,
4. Material structure and extrusions,
5. Component and product performance.

Then for each of these foci, there are a sequence of abilities or understandings that become the headings of the columns for which each of the PCK questions are asked. So under the first focus of 'Assemblies – back axle, seat and steering' there were three areas of abilities/understandings:
1. Material properties,
2. Material testing for suitability,
3. Understanding performance properties.

Generally the teachers found the process of CoRe development very useful in their planning. They stated it is something they will keep doing, and they will maintain their planning sheets as live documents to return to the following year. Even though it is time consuming, two of the teachers had already begun using the template in other aspects of their teaching. They felt as though the CoRe planning had positively impacted on the engagement of their classes, through their higher level of PCK.

KD described the use of the CoRe as helping to validate her rationale for being a teacher:
The way I got into teaching was to motivate students, to create enthusiasm with food. And putting it on paper highlighted that for me. I'm not just teaching them to a prescribed standard, I'm teaching them to understand their food, and how they can, you know, adapt it, change it, ensure that it works, or doesn't work and what they can do to fix it.

In addressing the main research question of this inquiry (What are the effective components of a CoRe for technology Education teachers?) the teachers recommended changes to the CoRe template based on their experience and on the implementation of their designed CoRe. The changes were not radical, and related to the practical nature of technological activity: the headings of the CoRe were restructured to provide a project focus, ideas were expanded to include abilities, and the pedagogical questions were modified to address both abilities and understandings. The consensus of the research team was that these changes would make it more suitable for technology teachers to use in the development of their PCK. This highlights a fundamental difference between the nature of scientific and technological knowledge, and confirms the validity of the rationale for the initiation of this research. Science has a well-established epistemology, leading to an established organisation of knowledge into accepted topics of inquiry. Technology on the other hand has a shorter history of study as a philosophical enterprise and no commonly agreed upon epistemology. This research contributes to the ongoing debate about the nature of knowledge in technology and the way knowledge empowers technological practice.

References

Braun, V. & Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2)*,* 77-101. doi: 10.1191/1478088706QP063oa.

Cohen, L., Manion, L., & Morrison, K. (2011) *Research methods in education* (7th ed). London, England: Routledge.

Compton, V. (2004) *Technological Knowledge: A developing framework for technology education in New Zealand.* Briefing Paper prepared for the New Zealand Ministry of Education Curriculum Project. https://nzcurriculum.tki.org.nz/content/download/.../**technological**-kn.do...

Compton, V. & Harwood, C. (2003) Enhancing Technological Practice: An Assessment Framework for Technology Education in New Zealand. *International Journal of Technology and Design Education 13*, 1–26.

Cutcliffe, J. R., and McKenna, H. P. (1999) Establishing the credibility of qualitative research findings: the plot thickens. *Journal of Advanced Nursing, 30*(2), 374–380.

De Miranda, M. (2008) Pedagogical content knowledge and engineering and technology teacher education: Issues for thought. *Journal of the Japanese Society of Technology Education 50*: 17–26.

Hume, A., and Berry, A. (2010) Constructing CoRes – A strategy for building PCK in pre-service science teacher education. *Research in Science Education 41*: 341–55.

Hynes, M. (2012) Middle school teachers' understanding and teaching of the engineering design process: a look at subject matter and pedagogical content knowledge. *International Journal of Technology and Design Education, 22*(3), 345-360.

Jones, A., and Moreland, J. (2004) Enhancing practicing primary teachers' pedagogical content knowledge in technology. *International Journal of Technology and Design Education 14*: 121–40.

Kay, G. (2012) Pedagogical content knowledge for practical work: the development of an analytic tool. Paper presented at the 20th Annual meeting of the Southern African Association for Research in Mathematics, Science and technology Education (SAARMSTE), Malawi.

Koehler, M., and Mishra, P. (2005) What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research 32*: 131–52.

Loughran, J., Berry, A., & Mullhall, P. (2006). *Understanding and developing science teachers' pedagogical content knowledge.* Rotterdam: Sense Publishers.

Loughran, J., Mulhall, P., & Berry, A. (2008). Exploring pedagogical content knowledge in science teacher education. *International Journal of Science Education, 30*(10), 1301–1320.

Love, T. (2015) *An examination of preparation experiences that influence technology and engineering educators' teaching of science concepts*. Presentation at the 102nd Mississippi Valley Technology teacher Education Conference, Nashville, TN, November.

McCormack, R. (2004) Issues of learning and knowledge in technology education. *International Journal of Technology and Design Education 14*(2), 21–44.

Rauscher, W. (2010) The technological knowledge used by technology education students in capability tasks. *International Journal of Technology and Design Education 21*(3), 291-305.

Rohann, E., Taconis, R. and Jochems, W. (2009) Measuring teachers' pedagogical content knowledge in primary technology education. *Research in Science and Technological Education 27*, 327–38.

Rohann, E., Taconis, R. and Jochems, W. (2010) Reviewing the relations between teachers' knowledge and pupils' attitude in the field of primary technology education. *International Journal of Technology and Design Education 20*, 15–26.

Sagor, R. (2000) *Guiding School Improvement with Action Research*. Washington, DC: Association for Supervision and Curriculum Development.

Shulman, L. (1987) Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22.

Wertsch, J. V. (1998). *Mind as action.* New York: Oxford University Press.

Williams, P.J. (2012) *Technology education for teachers*. Melbourne: Macmillan.

Williams, P.J., Eames, C., Hume, A., Lockley, J. (2012) Promoting pedagogical content knowledge development for early career secondary teachers in science and technology using content representations. *Research in Science & Technological Education 30*(3), 327-343.

Williams, J., and Lockley, J. (2012). Using cores to develop the Pedagogical Content Knowledge (PCK) of early career science and technology teachers. *Journal of Technology Education 24*(1), 34-53.