



L-Università ta' Malta
Faculty of Education

Department of Technology &
Entrepreneurship Education

PATT

Proceedings PATT 37

Developing a knowledge
economy through technology
and engineering education

Editors:

Sarah Pulé and **Marc J. de Vries**

3 - 6 June 2019

*University of Malta,
Msida Campus*



PATT 37

Developing a knowledge economy through technology and engineering education

Msida, Malta

June 2019

Sarah Pulé and Marc J. de Vries, eds.

Department of Technology and Entrepreneurship Education

Faculty of Education

University of Malta

ISBN: 9 789995 714796

First published in Malta in 2019 by the Department of Technology and Entrepreneurship Education

© University of Malta, Msida, , Sarah Pulé

Review Panel

Piet Ankiewicz	University of Johannesburg	South Africa.
Stephanie Atkinson	University of Sunderland	UK.
Cecilia Axell	Linköping University	Sweden.
Marc Anthony Azzopardi	University of Malta	Malta.
Moshe Barak	Ben-Gurion University of the Negev	Israel.
David Barlex	Brunel University London	UK.
Scott Bartholomew	Purdue University	USA.
Vomaranda Joy Botleng	Université de Bordeaux	France.
Jeffrey Buckley	Athlone Institute of Technology	Ireland.
Leonard Busuttil	University of Malta	Malta.
Mario Camilleri	University of Malta	Malta.
Donal Canty	University of Limerick	Ireland.
Marjolaine Chatoney	Aix-Marseille Université	France.
Osnat Dagan	Beit Berl College	Israel.
Michael Daugherty	University of Arkansas	USA.
Michael de Miranda	Texas A&M University	USA.
Marc de Vries	Delft University of Technology	Netherlands.
Elizabeth Deuermeyer	Texas A&M University	USA
Edward Duca	University of Malta	Malta.
Ronan Dunbar	Athlone Institute of Technology	Ireland.
Jonas Hallström	Linköping University	Sweden.
Eva Hartell	KTH Royal Institute of Technology	Sweden.
Dawne Irving-Bell	Edge-Hill University	UK.
Steve Keirl	Goldsmiths University of London	UK.
Nina Kilbrink	Karlstad University	Sweden.
Remke Marleen Klapwijk	Delft University of Technology	Netherlands.
Ruth Lemon	University of Auckland	New Zealand
Eila Lindfors	University of Turku	Finland
Carmel Navarro	University of Malta	Malta.
Sonja Niiranen	Tampere University of Technology	Finland.
Suzanne Piscopo	University of Malta	Malta.
Lorraine Portelli	University of Malta	Malta.
Sarah Pulé	University of Malta	Malta.
Marion Rutland	University of Roehampton	UK.
Niall Seery	Athlone Institute of Technology	Ireland.
Kay Stables	University of London	UK.
Torben Steeg	Manchester Metropolitan University	UK.
Francois Van As	University of Johannesburg	South Africa.
Gerald Van Dijk	Utrecht University of Applied Sciences	Netherlands.
John Williams	University of Waikato	New Zealand.
David Wooff	University of Sunderland	UK.

Organisation Board

Sarah Pulé, Carmel Navarro and the University of Malta conference unit.

Advisor and PATT Foundation representative

Marc J. de Vries.

Welcome to PATT 37 Msida, Malta

Developing a knowledge economy through technology and engineering education.

Technology is pervasive in modern life and the economies of countries usually depend on how this is understood, developed, used and critiqued. With the advent of technologies which might disrupt the way we operate, becoming technologically literate and developing technological habits of mind is increasingly important for societies that value human capital.

Design and Technology education can be seen to have multidimensional roles. Research stimulates debate about important concepts and helps to answer questions such as the following:

1. Is design and technology education only for developers or producers of technology, or is it suitable for all citizens?
2. What knowledge and skills within design and technology education are transferable to future contexts within the workplace or for life?
3. How can we democratize technological knowledge and skills through design and technology education?
4. Specialised technological knowledge versus generalised technological knowledge: which is more suited for developing a knowledge economy based on human capital?
5. How can design and technology education contribute to generating future workplaces based on creativity and innovation?
6. What pedagogies are most suited to design and technology education?
7. How can design and technology education prove useful for everyday life?
8. How can design and technology education help to develop cultural capital?
9. What are the expectations for learning outcomes from different educational levels of design and technology education, ranging from primary, secondary, post-secondary and tertiary education?

PATT conference 2019 is open to the research topics which inform on the topics above as well as others relevant to the area of technology education, such as: a) curriculum content, b) STEAM philosophy, c) classroom practices, d) technological vocational education, e) project based learning and assessment for technology education, f) design knowledge and processes etc.

PATT is an international community of technology education colleagues (researchers, teacher educators, teachers, etc.) who are interested in educational research as a support to developments in technology teaching. PATT is open to all. There is no membership. Proceedings of previous conferences can be found at the ITEEA website (<https://www.iteea.org/Activities/Conference/PATT/PATTConferences.aspx>).

PATT 37 is a historical milestone for Maltese education in Design, Technology and Engineering in Malta since it is the first international conference focused on the teaching of technology from the primary level of schooling, to secondary, post-secondary and tertiary. We believe that this conference will make an interesting, valuable and significant contribution to the scholarly discourses of Technology education. We are convinced that the introduction of an international perspective into technology education will act to inspire Maltese stakeholders to become more participant within the international community of researchers and we hope that Technology education will continue to grow and mature through scholarly analysis and communication.

Sarah Pulé and Carmel Navarro
University of Malta
Conference conveners
June 2019

PATT

PUPILS' ATTITUDE TOWARD TECHNOLOGY

PATT conferences began in 1985 when a small scale workshop on attitude research about technology was held in the Netherlands. Thus began a series of international conferences that continues today. In the early conferences, colleagues from different countries came together to discuss the possibilities and share research about exploring the attitudes of young people to technology, using an instrument that has been developed in the Netherlands, and is still used today. The format of the first PATT conference set the trend for future conferences – no keynote presentations, no parallel sessions and plenty of time for discussion. While the scope of the issues for discussion and the research presented has extended to all aspects of technology education, the conferences have fostered a strong community of scholars of Technology Education, many of whom regularly attend the PATT conferences.

Contents

A comparative study of the content of two documents: The Design and Technology National Curriculum in England and New Zealand's Technology curriculum.13

Stephanie Atkinson

Technology Education in a Sámi School: Using Cultural Artefacts as a Learning Tool.25

Cecilia Axell

Programming as a New Content in Swedish Preschool: What Is It and How Is It Done?39

Cecilia Axell, Karin Stolpe

A quantitative analysis of Maltese educational pathways and their impact on the take-up of the engineering profession.49

Marc Anthony Azzopardi, Brian Zammit, Daniel Micallef, Daniel Buhagiar, Monique Borg Inguanez, Fiona Sammut, Alexia Pace Kiomall, Mario Cachia, Sarah Pulé.

First, Last, Elsewhere ... Positioning Adaptive Comparative Judgment in the Design Learning Experience.....65

Scott Bartholomew, Liwei Zhang, Esteban Garcia Bravo, Greg J. Strimel

Another way of teaching programming.....75

Lars Björklund

Learning through design and make: Producing originally-thought-out products versus producing pre-designed products downloaded from data files.83

Vomaranda Joy Botleng, Stéphan Brunel, Philippe Girard

Teaching modelling using digital tools in secondary technology education: Teachers' experiences.....95

Helen Brink, Nina Kilbrink, Niklas Gericke

Investigating perceptions of intelligence as an approach to understanding female representation in technology and engineering education.....103

Jeffrey Buckley, Tomás Hyland, Niall Seery, Lena Gumaelius, Arnold Pears

Inducting ITE students in assessment practices through the use of comparative judgment.....117

Donal Canty, Jeffrey Buckley, Niall Seery

Integrative STEM Education - A New M.Ed. Program: Development, Objectives, and Challenges.	125
Osnat Dagan, Noa Ragonis, Daphne Goldman, Tili Wagner	
Scale Development for Measuring iDesign Content Connections in Pre-Service STEM Teachers.....	133
Elizabeth Deuermeyer, Michael A. de Miranda	
Curriculum Development in Technology Teacher Education: Integrating Epistemology, Pedagogy and Capability.	145
Ronan Dunbar, Jeffrey Buckley, Niall Seery	
Study of correlations between treatments of the didactic incidents and interactive decisions. Case of a technological teaching session in a Tunisian middle school.	155
Nour ElHouda Essefi	
The truth is in the boat: A case study of pedagogical content knowledge and technical skill development in pre-service technology education teachers.	167
David Gill	
Pre-service technology education teachers’ perceptions of experiential learning through makerspaces.	177
David Gill, Gerald Galway	
Laying down the “T” and “E” in STEM education: Design as the basis of an integrated STEM philosophy.	187
Jonas Hallström, Piet Ankwicz	
Teachers’ attitudes towards teaching programming in Swedish Technology education.....	195
Eva Hartell, Andrew Doyle, Lena Gumaelius	
Fashion design education: effects of users as design core and inspirational source.....	203
Neshane Harvey, Piet Ankwicz, Francois Van as	
The predictive capacity of spatial ability for knowledge retention in third level technology and engineering education.....	213
Tomás Hyland, Jeffrey Buckley, Niall Seery, Seamus Gordon	
Pre-Service Teachers’ Perceptions of Pedagogical Approaches to STEM Education; Design and Technology.	221
Dawne Irving Bell	

Re-designing Design and Technology Education: A living literature review of stakeholder perspectives.....	233
Dawne Irving Bell, David Wooff, Matt McLain	
Analysing ‘values’ in collaborative development of D&T education units.....	249
Ritesh Khunyakari	
Using CAVTA (Conversation Analysis and Variation Theory Approach) in a Learning Study on Welding.....	269
Nina Kilbrink, Stig-Börje Asplund	
Formative Assessment in Primary Design Education – involving pupils in clarifying the learning goal of divergent thinking.....	277
Remke Klapwijk, Niels van den Burg	
The body within the loop - identifying the metaphor ecology of educational resources in computer programming.....	289
Andreas Larsson	
A methodological approach to the study of indigenous curriculum design for Hangarau, Māori technological practice in Aotearoa-New Zealand.....	297
Ruth Lemon, Kerry Lee, Hemi Dale	
Design & Technology and Computer Science in the CAMAU Project: The Genesis of Learning Progression in the New Curriculum for Wales.....	313
David Morrison-Love, Peter Donaldson, Janine Barnes	
Developing university pedagogy in engineering higher education.....	327
Sonja Niiranen, Johanna Naukkarinen Lappeenranta	
How teachers value skills and content in Technology teaching in Swedish compulsory school – a “climate” change.....	335
Charlotta Nordlöf, Susanne Engström	
Models and modelling in technology textbooks.....	347
Per Norström	
The objectives of technology education: a fresh look at the foundations.....	355
Antti Pirhonen	
Developing a Methodological Approach to Measure Cognitive Load during Complex Problem Solving.....	361

Clodagh Reid, Conor Keighrey, Rónán Dunbar, Niall Murray, Jeffrey Buckley.

The academic study of food in the English curriculum for pupils aged 16-18 years: its demise and future prospects.373

Marion Rutland

The perceptions of self-assessment in basic education in craft, design and technology.381

Sari Saarnilahti, Eila Lindfors

Exploring the nature of young learners' convergent thinking during designing.389

Alice Schut, Nicolaas Blom

Introducing Middle School children to compulsory D&T: Does It Influence Their Choice of Subject Later On? A Case Study of Maltese State Secondary Schools.399

Marilyn Stellini, Sarah Pulé

Existential risk in technology education.413

Markus Stoor

What are they doing? Tool use and self-image of girls aged 9 to12 when engaging in technology education.421

Ulrika Sultan, Cecilia Axell, Jonas Hallström

Technology Students' attitudes towards STEM and interest in STEM careers: A South African perspective.431

Francois Van As

Technology teachers' attitude towards technology: An investigation of Chinese high school general technology teachers.445

Meidan Xu, P. John Williams

Facets of Creativity evidenced Through a Design and Technology Summer Programme.457

Daniel Zarb, Sarah Pulé

A comparative study of the content of two documents: The Design and Technology National Curriculum in England and New Zealand's Technology curriculum.

Stephanie Atkinson



Stephanie Atkinson
University of Sunderland
UK
stephanie.atkinson@sunderland.ac.uk

ABSTRACT

This paper presents the findings of a small-scale project that looked at whether the present Design and Technology (D&T) National Curriculum (NC) for England promotes the development of technological capability to support the generation of economic value through enhancing human capital. The English D&T NC has been in existence for 30-years with a number of iterations during that time. Throughout that time-span the technological world in which D&T education exists, has changed beyond all recognition. This paper looks briefly at the concept of the knowledge economy and the development of human capital in a technological world. It then examines whether the English NC for D&T has evolved through its various iterations. A comparison between the most recent edition of the D&T NC document and the latest New Zealand Technology document through an analysis of the words used in each document was carried out utilising the frequency of all the meaningful words in the two documents. The data would suggest that there has been little change in the English version through its various iterations whereas in the NZ document there is a focus that explicitly embraces the developing technological world. The conclusion from the analysis suggests that a more overt recognition of technological change is required in the next iteration of NC D&T if those both inside and outside the D&T community are to recognise and believe in the worth of the subject for the education of students in their acquisition of human capital that will enable them to fulfil a role in the successful economic development of England and indeed the United Kingdom.

Key words: design and technology; national curriculum; knowledge economy; human capital

Introduction

This paper presents the findings of a small-scale project that looked at whether the present Design and Technology (D&T) National Curriculum (NC) for England promotes the development of technological capability to support the generation of economic value through enhanced human capital. The NC has been in existence for thirty-years with a number of iterations throughout that time. Over the same period the technological world in which D&T education resides, has changed beyond all recognition. This paper looks briefly at the constructs of a knowledge economy, the development of human capital in a technological world and the connection between these theories and the D&T curriculum. The various iterations of the English D&T NC are identified and reasons for carrying out a comparative study of the content of *National Curriculum in England: Design and Technology programmes of study* (DfE, 2013) and the latest New Zealand *Technology in the New Zealand Curriculum* document (Ministry of Education, 2017) are revealed. This is followed by an explanation of the methodology used to analysis these documents. The findings are then discussed and conclusions are drawn.

Knowledge Economy

A knowledge-based economy is an economy in which knowledge is created, distributed and used to confirm economic growth and ensure international competitiveness (Hadad, 2017). It has been agreed both from a theoretical and empirical perspective that technology is a significant factor influencing such economic growth (e.g. Sulaiman et al. 2015). The transformation from the post-industrial/mass production economy of the mid-1990s to the present knowledge economy, sometimes described as the technology/human capital economy, is continuously accelerating due to globalization and technological developments (Hadad, 2017; Houghton & Sheehan, 2000; Powell & Snellman, 2004).

The major characteristics of a Knowledge Economy (KE) have been specified as, open innovation, education, knowledge management and creativity (Figure 1) with a fundamental structural component being the technological infrastructure required to sustain such an economy, particularly in terms of ICT capacity (Houghton & Sheehan, 2000; White et al, 2012). With the expansion of intellectual capital being driven by both creativity and innovation the importance of the development of such skills during the education of any future workforce has been highlighted (Mention, 2011). Due to the nature of technology related education it is appropriate that such skills should be embraced within technology-based subjects taught in schools today.

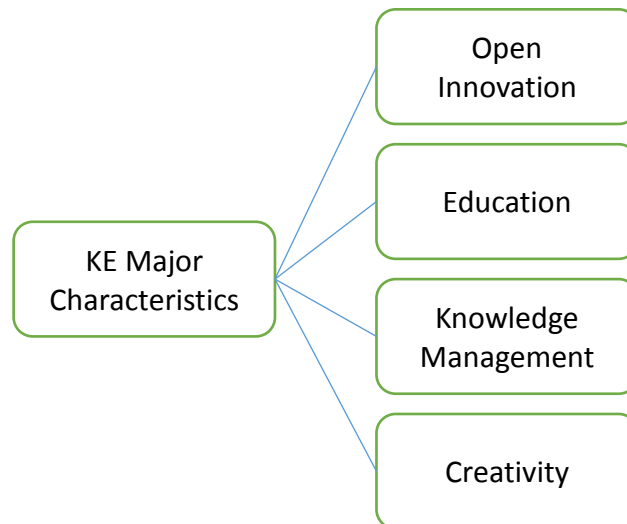


Figure 1: Major KE characteristics according to White et al. (2012)

Human Capital

Human capital, as part of intellectual capital, is seen as the stock of skills that the labour force possesses (Goldin, 2014). Bratianu & Balanescu (2008) summed these up as knowledge, intelligence and values. While Rindermann (2008) added that cognitive abilities were important not only for economic success but also for the non-economic success of individuals and societies.

A more comprehensive list of human capital skills was provided by Hadad (2017). His list included knowledge, skills, intelligence, personal agility, experience and intuition. He suggested that personal views, ideas, values, attitudes, and such abilities as creativity and know-how were also required. All of these can be skills that are developed through an appropriate technology-based curriculum. Goldin (2014) referring to human capital added her support for the importance of education, particularly in terms of technology, indicating that an understanding of its benefits to complement other learned skills would increase the return on any educational investment required. She also explained the cyclical nature of education which induced more technical change and new technologies which then increased the demand for superior skills. In other words, technological advances increase the demands for yet more human capital. In the knowledge economy people who possess, use and transfer knowledge are vital, with positive links firmly established between successful economies, human capital and education (e.g. Weber, 2011).

The History of the English D&T NC

The English D&T NC has been in existence for thirty-years with a number of iterations over that time period. The first statutory NC was published in 1989 when it was defined as being 'about identifying needs, generating ideas, planning, making and testing to find best solutions'. The next iteration was in 1995 with the introduction of a 'slimmed down' version although the philosophy and content of the curriculum changed little as the government agreed that the

principles found in the first Orders were still appropriate (Atkinson, 1997; NCC, 1992). The next version was in 1999. This time the focus of the whole NC changed to allow more time for teaching literacy and numeracy, detrimentally squeezing time allocated to other subjects. Although, once again there was little change in the NC D&T subject matter. Plans for reforms in 2007 were abandoned due to a change in government and it was not until 2010 that an 'expert review panel' reported on a new framework for the NC. This led to significant changes in NC structure with the government producing a draft edition early in 2013 followed by the final version later in the same year. In terms of D&T after vociferous condemnation of the very backward-looking draft edition (Atkinson, 2017), the final version was revised and is still in use today. It is the content of this version that is the subject of this paper.

These different iterations of the D&T NC have existed throughout a time of unprecedented, technological changes globally (Abbasi et al., 2017). New technologies have modified the way people live, work and develop their creative potential (Bonnardel & Zenasni, 2010). This paper suggests that because the English D&T NC has failed to change radically through its various iterations during this timeframe, it has been unsuccessful in keeping up with the technological world in which it sits, in comparison to some other countries' technology-based curricula. In order to garner data to support this belief a comparison was carried out of the content of the latest English document (DfE, 2013, p.1) which states that *'High-quality design and technology education makes an essential contribution to the creativity, culture, wealth and well-being of the nation'* and the latest NZ Technology Curriculum (NZ MoE, 2017, p.1) which states that *"with its focus on design thinking, the aim is for students to develop broad technological knowledge, practices and dispositions that will equip them to participate in society as informed citizens and provide a platform for technology-related careers"*. Both quotations would appear to suggest support for building students' human capital and the economic well-being of a nation in a forward-thinking manner. This paper therefore asks the question: does the content of the English D&T document support this supposition?

Methodology

In order to interrogate each curriculum's content the most recent English and NZ documents were downloaded from the Internet and converted into Word files. An assumption was made that the words would be indicative of the underlying philosophy, expectations and content of each curriculum. Word Cloud software (WordCloud.com) was then used to analyse the frequency of words used in order to draw conclusions about the content of each document. Support for the use of such software as a viable tool for academic purposes has been signposted by McNaught & Lam (2010).

In terms of the negative aspects of using Word cloud analysis, it was recognised that at best word frequency was *"...a quantification of qualitative data that could easily be misapplied or poorly interpreted"* (McNaught & Lam, 2010, p.634). It was also accepted that no weightings and therefore significance could be scientifically attributed to the count, and that as the Quirkos blog (2017) explained using this form of analysis was simply *"a one-dimensional dive into the data"*. However, it was still considered an appropriate way forward for this small-scale piece of research as comparison of the word clouds generated from different texts have been shown to reveal the differences between the ideas contained in those texts (McNaught & Lam, 2010) (Figure 2).



Figure 2: Word clouds of the meaningful words in the NC for D&T in England (on right) and the NZ Technology Curriculum (on left).

The first step in the analysis was the compilation of a ‘stop list’ of meaningless words so that the data was not swamped by extraneous words. The justification for excluding any words was carefully considered. This included removing cookery terms from the English document as food and cooking were not included in the NZ document and leaving in the associated words would have unhelpfully skewed the data.

Once the irrelevant words had been removed there remained 679 words in the English document and 841 words in the NZ document. The software produced a rank order list of meaningful words from each document using a continuum, most used word to least used word. Each word’s frequency was counted (Table 1) and then calculated as a percentage of the total meaningful words in each document. This data was carefully scrutinised leading to words being compared, classified, labelled and re-labelled until seven grouping categories were established. The category labels were: learning action words; words associated with abilities; outcomes; processes; equipment; the environment and subject content and materials. The two categories labelled ‘equipment’ and ‘the environment’ were excluded from any further analysis as words in these categories each appeared only once or twice, in comparison, to an average of thirteen occurrences for a word in the ‘learning action’ category.

The words in the five remaining categories were then compared in terms of word frequency across the two documents looking for similarities and differences. A final scrutiny of the rank order positions of the top-ten words in relation to the five established categories enabled further conclusions to be drawn.

Table 1: Indicates the total words used in each document, the occurrence of the most and least used word, the combined total of the top ten most used words and the percentage usage of the total of the top ten words

	English Document	NZ Document
Total meaningful words (MW)	679	841
Occurrences of the most used word	29	55
Occurrence of least used word	1	1
Total occurrence of the top-ten most used words	190	242
Total top-ten most used words as a percentage of total words used	27%	28%

Results

Meaningful Words

The rank order of the frequency of meaningful words established that the top-ten words used in the D&T document formed twenty-seven percent of the total meaningful words while in the NZ document it was twenty-eight percent (Table 1). This supported the author's belief that these top-ten words were important and portrayed the philosophical underpinning, direction and content of each curriculum. Scrutiny of the position of individual words in the top-ten word lists indicated significant frequency differences between the two documents (Table 2). It also revealed that in the English document there was only a difference of eighteen occurrences between the most used word and the tenth most used word. Whereas, in the NZ document there was a much greater variance with a difference of forty-five. Of significance was the drop of -17 between the top and second top word on the NZ list (Table 2). This seemed to indicate how important the top word, 'technology' was in the context of that curriculum. To tease out further the importance of individual words in each document the analysis of words in relation to each of the five identified categories is reported.

Table2: Indicates the Rank order of the ten most used words in each NC document, the number of occurrences, and the percentage in terms of the top-ten words and the total meaningful words (MW) used in each document

R O	English Document				NZ Document			
	Word	No. of Occurrences	% of Top10	% of total MW	Word	No. of Occurrences	% of Top10	% of Total MW
1	Design/designing	29	15.26	3.68	Technology	55	22.73	6.54
2	Understanding	28	14.74	3.46	Design/designing	37	15.29	4.40
3	Range	25	13.16	3.68	Digital	33	13.64	3.92
4	Use/using	22	11.58	3.24	Developing	33	13.64	3.92
5	Products	21	11.05	3.09	Outcomes	26	10.74	3.09
6	Technology	16	8.42	2.37	Knowledge	15	6.20	1.78
7	Making	13	6.84	1.92	Learn/learning	12	4.96	1.43
8	Applying	13	6.84	1.92	Thinking	11	4.55	1.31
9	Creative/creativity	12	6.32	1.77	Systems	11	4.55	1.31
10	Knowledge	11	5.79	1.62	Skills	10	4.13	1.19
Total		190	100%	27%	242		100%	28%

Categories

Words associated with Learning Actions:

The first category to be analysed, 'learning action' words with an average frequency occurrence of thirteen, revealed that in the English document 'understanding' was the most used 'learning action' word, while it only appeared eleventh in the NZ document. In contrast, 'developing' was the most used 'learning action' word in the NZ document and it was only eleventh in the English document. 'Using' was the fourth most used word in the English document but it was only the twenty-second most used word in the NZ document. It was also noted that five of the six 'learning action' words were in both documents, with three of them appearing in the top-ten words in each of the NZ and English documents, although they were

not the same words in each list (Table 3). The use and importance of ‘learning action’ words in each curriculum was not a surprise as the subject in both countries required ‘action’ in order to carry out pertinent activities.

Table3: Indicates the words in each Category, the rank order (RO) position in relation to the ten-top words in each separate document and a comparison with the other document’s rank order position

Words	Eng Doc RO	Comparison with NZ Doc RO position	NZ Doc RO	Comparison with Eng Doc RO position
<i>Words associated with Learning Actions – Average occurrence of words in this category 13</i>				
understanding	2 nd	+	11 th	-
developing	11 th =	-	3 rd =	+
using	4 th	+	22 nd =	-
learning	30 th =	-	7 th	+
thinking	-	-	8 th =	+
applying	8 th	+	81 st =	-
<i>Words associated with Abilities – Average occurrence of words in this category 6</i>				
Knowledge	10 th	-	6 th	+
Creative Thinking	9 th	+	47 th	-
Skills	17 th =	-	10 th	+
Computation	-	-	16 th =	+
Communication	-	-	16 th =	+
Perform	30 th =	+	-	-
Innovative	30 th =	+	-	-
Criticality	-	-	29 th =	+
<i>Words associated with Outcomes – Average occurrence of words in this category 7</i>				
Outcomes	-	-	5 th	+
Products	5 th	+	47 th	-
Ideas	13 th =	-	29 th =	+
Images	-	-	29 th =	+
Data	-	-	29 th =	+
Drawing	162 th =	-	127 th =	+
<i>Words associated with Processes – Average occurrence of words in this category 12</i>				
Designing	1 st	+	2 nd	-
Making	8 th =	+	-	-
Practical	13 th =	+	-	+
Processes	-	-	81 st =	+

Words associated with Subject Content & Materials – Average occurrence of words in this category in the D&T Document 6; Average occurrence of words in NZ document 23

Technology	6 th	-	1 st	+
Digital	-	-	3 rd =	+
Systems	30 th =	-	8 th =	+
Materials	22 nd =	-	12 th =	+
Computing	30 th =	-	16 th =	+

Words Associated with Ability:

The words associated with 'Ability' with an average frequency occurrence of six, were pertinent to the aims of each curriculum (DfE, 2013; NZ MoE, 2017) and were also linked to abilities associated with human capital (Hadad, 2017) and therefore the knowledge economy (Houghton & Sheehan, 2000; Mention, 2011; White et al, 2012). However, words in this category were of a lower frequency count than found in any of the other categories (Table 3). 'Knowledge' was the most used word in both documents. In the NZ document it was the sixth most used word while in the English document it was the tenth most used word. As an isolated word its relationship to this category was not obvious. However, when its role within each document was scrutinised further, uses of the word in conjunction with other words such as 'developing knowledge' and 'applying knowledge' indicated that 'knowledge' did belong in this category.

As well as similarities this category also highlighted several differences between the two documents. The word 'Skills' was an important word in the NZ document, it appeared as the tenth most used word whereas in the English document 'skills' was placed lower, at seventeenth. 'Creative thinking', another important ability in the context of a creative subject was the ninth most used phrase in the English document although it only appeared three times in the NZ document where it was ranked forty-seventh.

Words Associated with Outcomes:

In this category there was an average frequency occurrence of seven. Initial scrutiny of the use of the words 'Products' in the English document and 'Outcomes' in the NZ document implied words with similar meanings that were each ranked fifth in the total word count. However, a subtle difference was teased out by scrutinising the full text where the interpretation of an outcome in the NZ document suggested a broader more open meaning of 'a possible result or effect of an action', whereas the word product was more specific and inferred that a physical article must be manufactured. This difference was considered important and is returned to in relation to the next category.

Words associated with Processes

In this category the average frequency occurrence of words associated with 'processes' was seven. The importance of the word 'designing' as a process was illustrated by the positioning of the word in both documents. It was the most used word in the English document and the second most used word in the NZ document. This was unsurprising as the activity of designing

has always been at the centre of both curriculum's activities. However, another example of differences in direction was the fact that 'Making' as a process word was the eighth most used word in the English document and yet, it was not used at all in the NZ document. The high count of the word 'making' was seen to link with the word 'designing' in the English document where 'designing and making products' has always been at the heart of D&T. The use of the word 'outcomes' instead of 'products' in the NZ document with its subtle lack of assumption that all outcomes must include 'making a product' could be an explanation for 'making' not needing to appear in the NZ document. This author speculates that the emphasis in the English document on designing and making products, often a time-consuming activity, could be an inhibitor to the inclusion of more time for experimentation with new technologies.

Words Associated with Subject content & Materials

In this category there were very different levels of use of words associated with 'subject content and materials'. In the English D&T document the average was only six occurrences, whereas the average occurrence of words in this category in the NZ document was twenty-three. The use of the word 'Technology' was as expected found in both documents. It was the most used word in the NZ document with fifty-five mentions in comparison to only sixteen in the English document. It was the use of this word that caused the average occurrence of words in this category in the NZ document to be so high. More evidence of technology's importance in the NZ document was found in the use of the words 'digital', the third most used word and 'systems' which was the eighth most used word. In the English D&T document the word 'digital' did not appear at all and the word 'systems' was only ranked thirtieth. A third indication of the importance of technology in the NZ document was captured when a count of all words associated with 'technology' in that document indicated that they formed 17% of all the meaningful-words. The same analysis using the English D&T document found only 8% of the words were associated with 'technology'.

Discussion and Conclusion

Although the aims and therefore philosophy of the two documents were seen to be comparable, as stated earlier, and the data indicated important similarities in some words used throughout the two documents, the various analyses carried out in this small-scale project did provide evidence that what was expected to be carried out in the English D&T and NZ Technology classroom, differed considerably. The development of the necessary technological skills and understanding which many believe are increasingly important were overtly evident in the NZ document whereas in the English document reference to the use of such skills tended to be implicit, with a lack of reference to words associated with technology being explicitly expressed.

The analysis of the data would appear to support the author's belief that the English NC for D&T has failed to change enough through its various iterations over the past thirty years and has therefore been unsuccessful in keeping up with the technological world within which it sits in comparison to the most recent Technology Curriculum provided for students and teachers in New Zealand.

The data suggests that in England there is a need for more explicit recognition of technological developments in the next iteration of the D&T NC and that this needs to happen sooner rather than later if those both inside and outside the D&T community are to believe in the worth of the subject for the education of students both in terms of developing the broad skills, knowledge and understanding that a design and technology curriculum can provide as well as enabling the acquisition of human capital that will enable students to fulfil an important role in the successful economic development of England and indeed the United Kingdom in the future.

References:

- Abbasi, M., Vassilopoulou, P. & Stergioulas, L. (2017). Technology roadmap for the creative industries. *Creative Industries Journal*, 10 (1), 40-58
- Atkinson, S. (1997). *Identification of some causes of demotivation amongst Key Stage 4 pupils studying Design and Technology*. Unpublished PhD. Newcastle: Newcastle University.
- Atkinson, S. (2017). So what went wrong and why? In K. Baynes & E. Norman (Eds.), *Design epistemology and curriculum planning* (pp. 13-17). Loughborough: Loughborough Design Press.
- Becker, G. S. (1994). Human capital revisited. In G. S. Becker (Ed.), *Human Capital: A theoretical and empirical analysis with special reference to education (3rd Edition)* (pp.15-28). Chicago: The University of Chicago Press.
- Bonnardel, N., & Zenasni, F. (2010). The impact of technology on creativity in design: An enhancement? *Creativity and Innovation Management*. 19 (2), 180-191
- Bratianu, C., & Balanescu, G.V. (2008). Vision, mission and corporate values: A comparative analysis of the top 50 U.S. companies. *Management & Marketing*, 3 (3), 19-38
- Department for Education. (2013). *National Curriculum in England: design and technology programmes of study*. London: DfE
- Goldin, C. (2016). Human capital. In C. Diebolt & M. Hauptert (Eds.), *Handbook of Cliometrics*. Heidelberg, Germany: Springer Verlag. 55-86
- Hadad, S. (2017). Knowledge Economy: Characteristics and dimensions. *Management Dynamics in the Knowledge Economy*, 5 (2), 203-225;
- Houghton, J., & Sheehan, P. (2000). A Primer on the knowledge economy. Paper prepared for *The National Innovation Summit*, Melbourne: Department of Industry, Science and Resources, Canberra.
- McNaught, C., & Lam, P. (2010). Using wordle as a supplementary research tool. *The Qualitative Report*, 15(3), 630-643. Retrieved from <https://nsuworks.nova.edu/tqr/vol15/iss3/8/>
- Mention, A-L. (2012). Intellectual capital, innovation and performance: A systematic review of the literature. *Business and Economic Research*, 2 (1), 1-37
- National Curriculum Council, (1992). *National Curriculum Technology: The case for revising the order*. York: NCC
- New Zealand Ministry of Education. (2017). *Technology in the New Zealand Curriculum*. Retrieved from <http://nzcurriculum.tki.org.nz/The-New-Zealand-Curriculum/Technology>
- Powell, W. W. & Snellman, K. (2004). The Knowledge Economy. Annual Review of Sociology. Annual Reviews. Retrieved from <https://www.annualreviews.org/doi/abs/10.1146/annurev.soc.29.010202.100037>
- Quirkos,(2017, September 14). Using word clouds in qualitative research [Blog post]. Retrieved from <https://www.quirkos.com/blog/post/word-clouds-and-word-frequency-analysis-in-qualitative-data>

- Rindermann, H. (2008). Relevance of education and intelligence at the national level for the economic welfare of people. *Intelligence*. **36** (2),127–142.
- Sulaiman, C., Umar, B., Bulama, A. T., Salisu, I. W., & Ibrahim, K. M. (2015). Human capital, technology, and economic growth: Evidence from Nigeria, Sage Open:1-10. Retrieved from <https://cyberleninka.org/article/n/588132.pdf>
- Webber, A. S. (2011). The role of education in knowledge economies in developing countries. *Procedia Social and Behavioral Sciences*. 15, 2589-2594
- White, D. S., Gunasekaran, A., & Ariguzo, G. (2012). The structural components of a knowledge-based economy. *International Journal of Business Innovation and Research*, 7(4), 504-518

Technology Education in a Sámi School: Using Cultural Artefacts as a Learning Tool.

Cecilia Axell



Cecilia Axell
Linköping University
Sweden
cecilia.axell@liu.se

ABSTRACT

The aim of this study is to explore the nature of technology education in a Sámi school, in order to identify the potential of indigenous Sámi knowledge for broadening the horizons of technological literacy. This paper presents the findings from the initial analysis of the empirical material. The purpose was to identify which specific artefacts play a central role in technology education in a Sámi school, and how the artefacts are implemented in technology education to convey technological knowledge. The participants (teachers and pupils) were all from the same Sámi School in Northern Sweden. The method employed was participatory observation and empirical material consists of field notes, recorded conversations, photographs and children's drawings. The findings show that technology education is strongly connected to specific artefacts that are important in Sámi culture. Technology Education is grounded in a holistic view of knowledge and to a large extent integrated with other school subjects. The knowledge system embedded in technology teaching is collective and related to both artefacts and activities. Myths and storytelling are frequently used to contextualise the technological content, and the historical aspect of technology is largely present since connections between older and newer technological solutions are made. Technological knowledge, activities and specific artefacts are not only attributed a practical value, but also given a symbolic value, since a common knowledge base in Technology contributes to strengthening the children's cultural identity.

Key words: Technology Education, Indigenous Technology, Sámi School

Introduction

Technological literacy – essentially the capability to understand and use technology (e.g., ITEA, 2007; Jenkins, 1997) – is an increasingly central goal of technology education across the globe. Definitions of technological literacy vary from comprehensive to vocational, but most definitions rely primarily on Western knowledge systems (Gumbo, 2018; Marshall, 2000;

Williams, 2009). Students in many countries consequently also perceive the content of technology education in a narrow sense as being mainly about modern, Western artefacts such as computers, tablets and TVs (Dakers, 2006; de Vries, 2005; Svenningsson, Hultén & Hallström, 2018).

However, since technology is a global phenomenon, it is important that knowledge about it includes technology from different cultural contexts and not merely technologies produced and used in limited parts of the world (Edgerton, 2011; Gumbo, 2015; Ihde, 1990). Narrow conceptions of technological literacy are not only misleading when it comes to the global magnitude of technological culture but could also potentially marginalise indigenous knowledge systems in various parts of the world.

Research suggests that indigenous technology and knowledge systems can contribute to broadening the horizons of technology education and technological literacy (e.g. Ankiewicz, 2016; Bondy, 2011; Gumbo, 2015; Lee, 2011; Marshall, 2000; Seemann, 2000; 2010; van Wyk, 2000). One difference between western and indigenous technology is that the latter is often based on knowledge that has been developed over many generations (Bondy, 2011; Gumbo 2018). It is generally transmitted from one generation to the next through oral narratives, storytelling, music, symbols and art, as a way of maintaining a societal continuity (Owuor, 2007).

The Sámi are an indigenous people spread over four countries: Sweden, Norway, Finland and Russia. In 1981, the Swedish government established a Sámi School Board, responsible for Sámi schools with the mission to give Sámi children an education with Sámi orientation and teaching in the Sámi language. Today, there are five Sámi Schools in the Northern part of Sweden (Johansson, 2007; 2009; Svonni; 2015). However, Sámi knowledge has been included only marginally in the national curriculum in Sweden (Svonni, 2015), not to the same extent as countries such as South Africa (Vandeleur, 2010).

The Sámi curriculum in Sweden is equal to the general school curriculum for the compulsory school. However, in the Sámi curriculum it is emphasised that Sámi pupils should be given the opportunity to become familiar with Sámi cultural heritage (Balto & Johansson, 2015; Swedish National Agency for Education, 2018). The Sámi knowledge system is holistic, place-bound and based on inherited wisdom and knowledge. It is also often linked to practical applications and skills (Keskitalo & Määttä, 2011; Keskitalo, Määttä & Uusiatutti, 2012; Svonni, 2015).

The aim of this research project is to explore the nature of technology education in a Sámi school setting and examine in what ways indigenous Sámi knowledge can contribute to broadening the horizons of technological literacy. This paper is a presentation of the initial findings. The purpose was to identify:

- *Which specific artefacts* play a central role in technology education in a Sámi school, and
- *How* the artefacts are implemented in technology education to convey technological knowledge.

Theoretical Background

Keirl (2006) describes technological literacy as having three important dimensions: *the operational* (students learn to use and do the technology), *the cultural* (the students contextualise their learning) and *the critical* (students learn about and how to be with technology). Since the cultural aspect is central in this study, Ihde's (1993) broad definition of

technology is used when analysing the data: i.e. that technology has some concrete components, that humans use these components in praxes and that there is “a *relation* between the technologies and the humans who use, design, make, or modify the technologies in question”(p. 47). According to Ihde (1990; 1993), technologies cannot be understood as an independent power since they are always interwoven with culture. Culture as a concept is complex but can be explained as being connected to *how* and *why* we do things. ‘How’ is about our material practice, while ‘why’ is connected to the meanings (James, 2015).

The technology that surrounds us shape our lives, our environments, our cultures, our thinking, and our being in the world (Kaplan, 2009; Keirl, 2015). Thus, technology can be described as having physical and intentional properties. The physical properties interact with other physical things in the world, whereas intentional properties relate to human beliefs, desires and purposes (de Vries, 2005; Kaplan, 2009; Kroes & Meijers, 2002). An artefact is hence a result of both physical and contextual conditions (Kroes & Meijer, 2002; Vermaas, Kroes, van de Poel, Franssen & Houkes, 2011).

Artefacts play an important role in teaching and learning about technology. To explore their compositions, the material they are made of, their design and their possible functions can support students’ interest and knowledge in technology (de Vries, 2005). However, a problem highlighted in previous research is that students often are not given the opportunity to analyse the technology in a meaningful context. Consequently, the connections between artefacts and humans, and what kind of implications the artefacts have in a societal/cultural context, are overlooked (Mawson, 2010; Siu & Lam, 2005; Turja, Endepohls-Ulpe & Chatoney, 2009).

Methodology

The method employed in this study was participatory observation. Marshall and Rossman (2011) define observation as “the systematic noting and recording of events, behaviors, and artifacts (objects) in the social setting” (p.139). Participatory observation enables the researcher’s involvement in a variety of activities over an extended period and therefore provides a deeper understanding of the studied field (DeWalt & DeWalt, 2002). The observations can be of different degrees: non-participation, passive participation, active participation and full participation (Spradley, 1980).

The participants (teachers and pupils) are all from the same Sámi compulsory school in Northern Sweden. The school provides education from preschool class to year 6, children aged 6 to 12. The study followed Swedish Research Council’s (2017) ethics considerations and guidelines and the participating pupils had their caregivers consent to partake in the study. The data was collected during a period of two years and during four visits to the school. Each visit lasted four to six days.

The data consists of observations of the daily activities with the pupils, as well as teacher meetings and other events of the school day. The participating observations varied depending on activity, and they were recorded by field notes, photographs, audio recorded interviews/conversations and children’s drawings. In the classrooms, both Swedish and Sámi languages were spoken, as the pupils’ knowledge of the Sámi language varied. However, when teaching was carried out in Sámi, the teacher translated and explained to the author afterwards.

The material was analysed by using a qualitative content analysis inspired by Erlingsson & Brysiewicz (2017) description, i.e., a repeated and interpretive process in which the meaning of a part can only be understood as related to the context. Based on the research questions, the objective was to identify recurring themes in the empirical material.

Findings

The initial analysis of the material showed that there were some specific *artefacts* that functioned as starting points for various activities related to technology, including

- Sámi footwear (Bellinge-shoes)
- Sámi Shaman drum

The activities connected to these artefacts, took place with year 2 and 3 pupils (8-9-year-olds). In the following descriptions of the technology activities, parts of field notes and photographs have been selected as illustrations of what was found significant for how the artefacts were implemented in the technology teaching. *The quotations have been translated into English by the author.*

Activity 1: The Sámi leather shoe – making threads of reindeer sinews

The traditional Sámi winter shoes are made of hide from the legs of the reindeer. Since the hide is thicker in different places on the reindeer's legs, it is important that each piece is put in the right place. On the underside, the fur pieces are placed in two directions, so the wearer will not slip (Figure 1 and 4). The toe hook was originally for putting on skis.



Figure 1: A Sámi Bellinge-shoe.

Narratives such as fairy tales and myths are often used in the teaching in this school, and the teacher introduces the activity for the pupils by reading aloud in Sámi from a Sámi picture book, *Silbamánnu “Silver Moon”* (Horndal, 2016). The story is about a Sámi girl who is very good at spinning threads. One day, she is captured by Stallo, a well-known character in Sámi mythology. Stallo is a giant troll who eats people. However, the girl outwits Stallo by releasing one of her threads, all the way to the place she is held captive. She is rescued and Stallo is killed. The picture book contains illustrations of artefacts with an old history; Sámi clothing, Sámi shoes, a wooden spindle, a wooden milk bowl, a walking stick, and longbows. However, modern artefacts such as a snowmobile, binoculars, a walkie talkie, and electric power lines are also depicted.

The teacher gathers the pupils in a circle on the floor. She has brought an old Sámi wooden spindle – like the one found in the pictures in the book (figure 2). The teacher shows the spindle to the pupils and uses its Sámi name. She has also brought a bag with sheep wool and takes a wad of wool and rolls it against her leg (figure 3).

The teacher: “You soak it a little bit like this [with water] ... and put the threads over each other. Look, now it becomes a little bit longer! I can use these threads to knit a sweater. ”



Figure 2: A Sámi wooden spindle.



Figure 3: The teacher rolls the wool.

The teacher: “But if I’m going to sew shoes [...] I need a strong thread.”

The teacher shows a Sámi winter shoe made of reindeer hide. She has also brought an object that looks like a bunch of yellow, thick threads.

The teacher: “What is this? Banana peel?”

A boy: “Sinews!”

The teacher: “Where are they from, the reindeer sinews? Where can you find them?”

A girl: “Behind somewhere.”

The teacher: “Yes, they are on their legs, so they can move.”

The teacher puts sinews on a wooden board and starts to process them with a rubber hammer (figure 5).

The teacher: “Look, now I have loose threads ... When they are this small, I soak them ... [she soaks the threads with some water from a cup], and then I spin them like this, against my leg.”



Figure 4. A Sámi shoe made of hide.



Figure 5. The teacher works the reindeer sinews.

She puts several threads together and rolls them back and forth on her leg.

The teacher: “Now it’s finished. Look, how nice! There are 12 threads ... I’ve got these from my mother [the sinews].”

The teacher passes some sinews to the pupils. She repeats the Sámi word for “sinews”.

A girl: “I have sewn with sinews at home.”

All pupils are given the chance to work the sinews with the rubber hammer and then twist the threads with help from the teacher. The challenge is to let the threads split. The pupils explore the structure of their threads. One of the boys pulls the thread to see how strong it is and realise that it is very hard to break:

A boy: “You can use it as dental floss!”

The teacher: “Yes, if you don’t have sinew threads, you can use dental floss [to sew the shoe].”

Most of the pupils want to use the sinew threads as bracelets and the teacher helps them tie the threads around their wrists.

In the afternoon, the class watch an old documentary about the lives of the Swedish Sámi people. While watching the film, the teacher points out things that can be linked to the activity with the sinews, as well as another activity in technology they previously had carried out: building a model of a *lavvú* (a Sámi dwelling).

The teacher: “Look, they used shoe hay instead of socks in the past.”

One of the children immediately respond to what the teacher said:

A girl: “I have done that!”

By comparing past and present, as well as confirming what the pupils say, the teacher makes links between older technological solutions and newer.

Activity 2: The Sámi Shaman Drum

According to the teacher, the Sámi shaman drum has never been a “magic drum”, even if it was given that epithet by those who had the intention to eradicate Sámi religion. The use of the drum was forbidden, and the drums were collected and burned. Today, not many are preserved, but according to the teacher it is still a strong and important Sámi *symbol*.

The Sámi drum project starts with a visit to the new Town Hall, and the teacher gives the pupils the task to memorise what the handles of the doorway look like. Back in the classroom, the teacher introduces the technology project by showing pictures on the Smartboard. The first one is a photo of the handles on the Town Hall door (figure 6).



Figure 6. The handles of the Town Hall door.

The teacher: “Why do the handles look like this?”

A girl: “Drums.”

The teacher: “That’s right! They are made of birch and the white is reindeer horn, and there are engraved signs. They look like the bottom of an old drum, which the Sámi used. And what did they use them for?”

A girl: “To know where to find reindeer grazing.”

The teacher: “Yes, it was used to see where to go with the reindeer, to make sure that childbirth went well, and where to find moose to hunt. With the help of the drum, they talked with the Gods and it was the Noaidi [the shaman] who used it. [...] Then people from outside arrived. They were Christians and they said that [the Sámi] should not believe in this. The drums were collected and burned. One man was also burned when he refused to give up his drum. Some [of these people] thought the drums were nice ... they brought them to Rome, Paris ... Today only 71 remain. But last year they found one behind a stone. It had begun to rot.”

The teacher shows a picture of a drum decorated with bear teeth.

The teacher: “The bear was holy. It has a skeleton that looks like a human skeleton [...] every sign [on the drum] means something. The signs are popular today, but [people] do not know what they mean.”

The teacher presents pictures of drums decorated with illustrations of Sámi Gods, and talks about the different roles they had in the mythology. The pupils receive a sheet of paper on which the Gods’ symbols are depicted (figure 7). They are given the task to write down facts about four of the them, the Goddesses who have their residence in the *lavvú*. In the conversations about the drum, the teacher and the pupils make connections to the *lavvú* activity. The fact that each technology activity is linked to many different perspectives and subjects can be interpreted as that the teaching is based on a *holistic view* of knowledge.

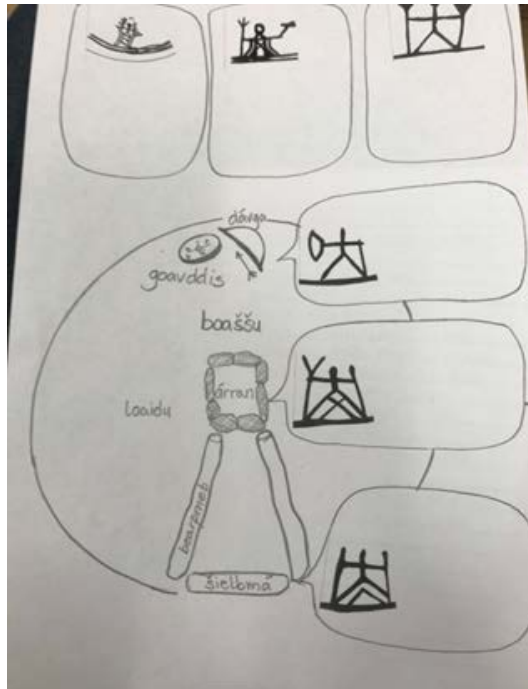


Figure 7. Sámi symbols of Goddesses.



Figure 8. Preparation of the Sámi Drum.

The teacher has prepared 12 frames, made of concrete to form cylinders.

The teacher: “We’ll be stretching hide tomorrow, but you have to prepare. Paint any colour you like. When you have finished and it has dried, you can paint symbols.”

The teacher gathers the pupils around a table and shows how to mix colours, and they start painting their drums (figure 8).

The teacher: “Here, I have a technical solution!”

In order to make the painted drums dry faster, she has fetched a hair dryer.

The researcher: “Is the drum ... “technology?”

A girl: “Yes, [it’s technology] because you can use it to find grazing for the reindeer and to cure diseases.”

While decorating the drums with symbols, the teacher and the pupils discuss the historical illustrations (figure 9). Just as with sinew thread activity, the teacher *links the past with the present*.

The teacher. “They depicted things that were important for them. What symbols could [be] on the drum if it was used today? A car? A computer ...?”

The following day, it is time to attach the drumheads to the drums. The teacher has brought 12 circular reindeer leathers. She gathers the pupils in a circle on the floor and demonstrates how the reindeer hides have been scraped with a specific tool and tanned in a decoction of water and willow bark.



Figure 9. The pupils decorate their drums with symbols.



Figure 10. The pupils explore the structure of the hides and the willow bark.

The hides are wet and kept in a plastic bag and the teacher explains this is to stop them from drying out. The pupils explore the structure of the hides and how stretchable they are (figure 10). The teacher then assists the pupils to attach the drumheads to the frames using a staple gun (figure 11).

The teacher. “But you will probably also have to fasten [the hides] with bolts and screws and attach a ribbon over. They will tighten as they dry.”

While waiting for assistance to fasten the hide, the pupils are told to draw a drum on paper. The teacher says they are free to decorate it with old symbols, but they can draw things that are important for them personally as well.

The teacher. “It was probably how they thought in the past too.”

Some pupils draw pictures of the Sámi Gods, of reindeer and Sámi dwellings, while others write names of relatives and pets. The drums are then left to dry (figure 12).



Figure 11. A staple gun is used to attach the drumheads.



Figure 12. The drums are left to dry.

In both the described activities, the teacher's pedagogy is characterised by a "show-and-copy" strategy. This can be interpreted as a natural choice since the technological knowledge linked to the specific cultural artefacts is *collective* and passed on from one generation to the next.

Conclusions

From the content analysis the following themes emerged:

- Cultural artefacts
- Links between past and present
- Myths and storytelling
- Collective knowledge
- Holistic view of knowledge
- Symbolic value

Technology education in this Sámi school can be described as strongly connected to *specific cultural artefacts*. Previous research indicates that too strong a focus on artefacts can have the consequence that the connections between artefacts, humans and culture are disregarded (Mawson, 2010; Siu & Lam, 2005; Turja, et al., 2009), but the findings in this study demonstrate the opposite. By using artefacts with a strong connection to culture and a focus on 'how' the artefact is used and 'why' (James, 2015), the activities become meaningful for the pupils. The artefacts are presented as having both physical and intentional properties (de Vries, 2005; Kaplan, 2009; Kroes and Meijers, 2002), and as being a result of cultural conditions (Ihde, 1990, 1993; Kroes & Meijers, 2002; Vermaas, et al., 2011).

There is also a strong *link between past and present*. Although the knowledge is old, it remains important and relevant. By using the cultural artefacts as a starting point in the teaching, the pupils are given the opportunity to see that technology is more than high-tech; it is an age-old tradition of problem solving, modification and adaptation to fulfil human needs (Lee, 2011). The teacher makes connections between older and newer technological solutions, which creates opportunities for the pupils to develop an understanding of the driving forces behind technological development and change and how objects in pupil's daily life have changed over time (Swedish Agency for Education, 2018).

Myths and storytelling, are important teaching elements, frequently used to contextualise the technological content. The knowledge is to a large extent conveyed orally by the teacher but often, known to some extent, by the pupils. Their responses indicate that they have obtained

this knowledge in a context outside school. These findings are in line with Owuor (2007) who notes that indigenous knowledge and skills are often transmitted from one generation to the next through narratives, symbols and art. This also confirms previous research that suggests that narratives and stories can be used in technology education to contextualise the technological content (Axell, 2015, 2017, 2018).

The technological knowledge mediated in this Sámi school can thus be described as connected to inherited knowledge, but also linked to practical applications and skills (Keskitalo & Määttä; 2011; Keskitalo et al., 2012; Svonni, 2015). During the activities, the teacher and pupils frequently refer to activities outside school, which confirms that indigenous technology is *collective* and based on knowledge that has been developed over many generations (Bondy, 2011; Gumbo, 2018). Additionally, technology teaching is implemented by using a thematic approach, including other school subjects like Natural Sciences, Religion, History and Crafts. This confirms that the knowledge system is holistic (Keskitalo & Määttä; 2011; Keskitalo et al., 2012; Svonni, 2015). It also indicates technological literacy in this Sámi school is grounded on a *holistic view of knowledge*. Technological knowledge, activities and specific artefacts are attributed a practical value, but also given a *symbolic value*, since a common knowledge base in technology contributes to strengthening the children's cultural identity.

To summarise, this study confirms that artefacts can play an important role in technology education (de Vries, 2005). The findings indicate that indigenous knowledge can contribute to broadening the horizons of technology education (Ankiewicz, 2016; Bondy, 2011; Gumbo, 2015; Lee, 2011; Marshall, 2000; Seemann, 2000, 2010; van Wyk, 2000). By using artefacts that are of importance to Sámi culture as a starting point, several of the objectives in the Technology Curriculum can be achieved.

References

- Ankiewicz, P. (2016). The relevance of indigenous technology knowledge systems (ITKS) for the 21st century classroom. In: M. J. de Vries, Arien Bekker-Holtland, G. van Dijk (Eds.), *PATT32 Proceedings Technology Education for 21st Century Skills: Utrecht, The Netherlands, August 2016*. (pp. 22-34). Utrecht, The Netherlands: University of Applied Sciences. Retrieved from www.patt2016.com.
- Axell, C. (2015). *Technology landscapes in children's literature. A didactic journey from Nils Holgersson to Pettson and Findus*. Dissertation. Linköping, Sweden: Linköping University.
- Axell, C. (2017). Critiquing literature: Children's literature as a learning tool for critical awareness. In P. J. Williams & K. Stables (Eds.), *Critique in Design and Technology Education. Contemporary issues in Technology Education* (pp. 237-254). Singapore: Springer Nature.
- Axell, C. (2018). Technology and children's literature. In M.J. de Vries (Ed.), *Handbook of Technology Education* (pp. 895-911). Cham, Switzerland: Springer International.
- Balto, A. M., & Johansson, G. (2015). The Process of Vitalizing and Revitalizing Culture-Based Pedagogy in Sámi Schools in Sweden. *International Journal About Parents in Education*, 9(1), 106-118.
- Bondy A. (2011). Indigenous knowledge, intellectual property and technology education. *International Journal of Learning*, 18(1), 389-400.

- de Vries, M.J. (2005). *Teaching about technology: an introduction to the philosophy of technology for non-philosophers*. Dordrecht: Springer.
- Dakers, J.R. (2006). Introduction: Defining technological literacy. In J.R. Dakers (Ed.), *Defining technological literacy: Towards an epistemological framework* (pp. 1-2). New York: Palgrave Macmillan.
- DeWalt, K.M. & DeWalt, B.R. (2002). *Participant observation: a guide for fieldworkers*. Walnut Creek, CA: AltaMira Press.
- Edgerton, D. (2011). *Shock of the old: Technology and global history since 1900*. London, UK: Profile books.
- Erlingsson, C. & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African Journal of Emergency Medicine*, 7(3), 93–99.
- Gumbo, M.T. (2015). Indigenous technology in Technology Education Curricula and teaching. In P. Williams, A. Jones, & C. Bunting (Eds.), *The future of Technology Education: Contemporary issues in Technology Education* (pp. 57-75). Singapore: Springer.
- Gumbo, M.T. (2018). Rethinking teaching of technology: An approach integrating indigenous knowledge systems. In M.J. de Vries (Ed.), *Handbook of Technology Education* (pp. 807-825). Cham, Switzerland: Springer International.
- Horndal, S. (2016). *Silbamánnu*. Karasjok: CálliidLágádus.
- Ihde, D. (1990). *Technology and the lifeworld: from garden to earth*. Bloomington, IN: Indiana Univ. Press.
- Ihde, D. (1993). *Philosophy of technology: An introduction*. (1st ed.) New York, NY: Paragon House.
- International Technology Education Association (ITEA). (2007). Standards for technological literacy: Content for the study of technology. Retrieved from: <https://www.iteea.org/File.aspx?id=67767>
- James, P. (2015). *Urban sustainability in theory and practice: circles of sustainability*. Abingdon, Oxon: Routledge.
- Jenkins, E. W. (1997). Technological literacy: Concepts and constructs. *The Journal of Technology Studies*, 23(1), 2-5.
- Johansson, G. (2007). *Cultural diversities in education in the North*. Research Report. Luleå University of Technology. Department of Education.
- Johansson, G. (2009). Cultural knowledge in school curriculum in practice: decolonizing processes and school development at Sámi Schools in Sweden. WIPCE 2008. Melbourne: Victorian Aboriginal Education Association.
- Kaplan, D.M. (2009). How to read technology critically. In: J.K. Berg Olsen, E. Selinger & S. Riis (Eds.). *New Waves in Philosophy of Technology* (pp. 83-99). London: Palgrave Macmillan.

- 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.
- Keirl, S. (2015). "Seeing" and "interpreting" the human-technology phenomenon. In P. J. Williams, A. Jones, & C. Bunting (Eds.), *The future of technology education* (pp. 13–34). Singapore: Springer.
- Keskitalo, P. & Määttä, K. (2011). How do the Sámi culture and school culture converge - Or do they? *Australian Journal of Indigenous Education*, 40, 112–119.
- Keskitalo, P., Määttä, K. & Uusiautti, S. (2012). Sámi education in Finland. *Early Child Development and Care*, 182(3–4), 329–343.
- Kroes, P., & Meijers, A. (2002). The dual nature of technical artifacts: Presentation of a new research programme. *Techné: Research in Philosophy and Technology*, 6(2), 4-8.
- Lee, K. (2011). Looking back, to look forward: Using traditional cultural examples to explain contemporary ideas in Technology Education. *Journal of Technology Education*, 22(2), 42–52.
- Marshall, J.D. (2000). Technology education and Indigenous Peoples: the case of Maori. *Educational Philosophy and Theory*, 32(1), 119-131.
- Marshall, C. & Rossman, G.B. (2011). *Designing qualitative research*. (5. ed.) Los Angeles: Sage.
- Mawson, B. (2010). Children's developing understanding of technology. *International Journal of Technology and Design Education*, 20(1), 1-13.
- Owuor, J. (2007) Integrating African indigenous knowledge in Kenya's formal education system: The potential for sustainable development. *Journal of Contemporary Issues in Education*, 2(2), 1718-4770.
- Seemann, K.W. (2000). 'Technacy education: towards holistic pedagogy and epistemology in general and indigenous/cross-cultural technology education'. *Proceedings of Improving practice through research: improving research through practice, 1st biennial International Conference on Technology Education Research* (pp. 60-74). Surfers Paradise, Qld, 7-9 December, Technology Education Research Unit, Griffith University, Nathan, Qld.
- Seemann, K.W. (2010). Learning how everything is connected: Research in holistic and cross-cultural indigenous technacy. Paper presented at *International Conference of Research in Technological Learning & Thinking*, University of British Columbia 17–21/06/2010, Vancouver, Canada.
- Siu, K. W. M., & Lam, M. S. (2005). Early childhood technology education: A sociocultural perspective. *Early Childhood Education Journal*, 32(6), 353–358.
- Spradley, J. P. (1980). *Participant observation*. New York: Holt, Rinehart and Winston.

- Swedish National Agency for Education (2018). *Curriculum for the compulsory school system, the pre-school class and school-age educare 2011*. Revised 2018. Stockholm: Norstedts Juridik AB.
- Swedish Research Council. (2017). *Good research practice*. Stockholm: Swedish Research Council.
- Svenningsson, J., Hultén, M., & Hallström, J. (2018). Understanding attitude measurement: Exploring meaning and use of the PATT Short Questionnaire. *International Journal of Technology and Design Education*, 28(1), 67–83.
- Svonni, C. (2015). At the margin of educational policy: Sámi/Indigenous peoples in the Swedish National Curriculum 2011. (2015). *Creative Education*, (9), 898-906.
- 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 Design and Technology Education*, 19(4), 353–336.
- Vandeleur, S. (2010). *Indigenous technology and culture in the technology curriculum: starting the conversation: a case study*. South Africa, Africa: Rhodes University, Faculty of Education.
- van Wyk, J.A. (2002). Indigenous knowledge systems: Implications for natural science and technology teaching and learning. *South African Journal of Education*, (4), 305-312.
- Vermaas, P., Kroes, P., Poel, V.D.I., Franssen, M., & Houkes, W. (2011). *A philosophy of technology: From technical artefacts to sociotechnical system*. San Rafael, CA: Morgan & Claypool.
- Williams, P. J. (2009). Technological literacy: A multiliteracies approach for democracy. *International Journal of Technology and Design Education*, 19(3), 237–254.

Programming as a New Content in Swedish Preschool: What Is It and How Is It Done?

Cecilia Axell, Karin Stolpe



Cecilia Axell
Linköping University
Sweden
cecilia.axell@liu.se



Karin Stolpe
Linköping University
Sweden
karin.stople@liu.se

ABSTRACT

In 2017, the Swedish government decided on a new national strategy for digitalisation of the school system. The strategy resulted in a revision of the curricula for Swedish preschool in order to strengthen digitalisation. Although programming is not explicitly mentioned in the curriculum, programming and robots have become a more common feature of preschool teaching. There are intervention studies showing that children can develop programming skills and conceptions. However, studies of programming from a technology education perspective are rare, and there is a need for further research. This study aims to investigate how programming in a preschool context and what the teachers and children do. This study focuses on the interaction between children, teachers and technology. The programming activities in preschool are not a separate activity, but part of a wider context, hence we adapt a sociocultural perspective. The empirical data consist of two group interviews with preschool teachers and one video-recorded programming activity with children aged 4-5 years and their teachers. The data material was analysed using a thematic content analysis to inductively search for patterns in the actions and methods used by teachers and children. This study shows that four aspects of programming were communicated: *instructions*, *sequences*, *bugs*, and *language*. Moreover, the relationship between humans and the technological artefacts was characterized in three different ways: technology as I) *anthropomorphic*, II) *gender coded*, and III) *autonomous or non-autonomous*. Thus, the programming activities and robot were incorporated in a wider context. Technology (the robot) became a tool to achieve several learning objectives. The technology was not the main focus; the overall message constructed in this teaching setting is that the human controls and uses the technology to achieve specific purposes.

Keywords: preschool, programming, technology education

Introduction

In 2017, the Swedish government, decided on a new national strategy for digitalisation in the school system. Digital competence for all and equal access and use of digital tools are two of the prioritized goals (Ministry of Education, 2017). The strategy has resulted in a revision of the curricula for Swedish preschool in order to strengthen digitalisation. Additionally, in recent years there has been a trend of including more digital tools and programming or coding content in schools and preschools. According to the Swedish Curriculum for the Preschool (Swedish National Agency for Education, 2018): “Education should [...] give children the opportunity to develop adequate digital skills by enabling them to develop an understanding of the digitalisation they encounter in everyday life.” (p.10). However, even though programming is not explicitly mentioned in the curriculum, programming and robots are becoming more common in preschool teaching (Kjällander, Åkerfeldt & Petersen, 2016). In this paper we use the term “programming”, as the overall problem-solving process that implies exploratory learning since it is the official term used in the English version of the Swedish curriculum for the compulsory school.

Since programming in preschool is still a new topic, there is little research. However, there are some intervention studies showing that children can develop programming skills and conceptions (e.g., Bers et al. 2014; Sullivan & Bers, 2016). There is research claiming that sequencing is an important component of early mathematics and literacy learning and consequently for the preschool ages. Researchers argue that it is possible to develop these skills by using robotics and programming (Kazakoff, Sullivan & Bers, 2013). Furthermore, Janka (2008) explains how Bee-Bot®, a programmable small robot, has been used in role-play activities in preschool. Her conclusion is that the children are not very interested in the Bee-Bot® itself and how it works. However, when the Bee-Bot® was a part of an open-ended story created by the children, some of the children showed understanding of how to control the Bee-Bot’s movements, while others showed a lack of self-confidence. Janka also suggests working in very small groups of no more the five children. It is also important that the teacher takes active role in encouraging the participation of all children (Janka, 2008).

In Sweden, there has been a request for research on programming in schools and preschools (Kjällander, Åkerfeldt & Petersen, 2016). Building on the premise that learning is mediated by social interaction and cultural artefacts as language and computers, this study is based on sociocultural perspective (Vygotsky, 1962; 1978) and we focus on the interaction between children, teachers and technology.

Two contrasting perspectives between humans and technology have been suggested: technology lives its own “life”, independent of human actions (determinism) or technology is a result of human activities, hence humans rule technology (Ellul, 1964; Winner, 1977). On the other hand, Pannabecker (1991) claims that alternative perspectives are needed in technology education to understand the complex relationship between humans and technology. Ascribing human attributes to animals or technological artefacts is common in children’s literature and movies (Axell, 2015). Anthropomorphism is suggested as a way to bridge the barrier between humans and the complex technology and build emotional bond between them (Axell, 2015; Waytz, 2014).

This study investigates programming in a preschool context and the actions and methods of teachers and children. We use the term *programming activities* for activities that are defined by the preschool teachers as programming activities. In doing so, we want to show how preschool teachers, together with the children, construct new content in a preschool setting.

1. How are programming activities conducted in a preschool setting?

2. What is the relationship between participants (teachers and preschool children) and technological artefacts?

Methodology

This study was conducted in a small municipal preschool (children 3-5 years old) in a middle-sized Swedish city. The preschool director had prioritized working with digital tools. In this study, four preschool teachers participated (all women).

The empirical data consist of two group interviews and one video-recorded programming activity. Four preschool teachers participated in the first group interview, where they discussed the programming project and their forthcoming projects. A second interview was conducted approximately six weeks after the first with three preschool teachers participating. The teachers discussed the programming project activities so far and showed pictures from the activities with the children. Furthermore, they discussed their plans for the upcoming teaching section.

The group interviews were audio-recorded and later transcribed. The first interview lasted for about one hour and the second interview was 25 minutes long.

In total, two groups of children participated in the programming project. The “yellow” group comprising three-year-old children and the “blue” group with children between 4-5 years old. In the teaching activity that was video-recorded as part of this study, four children from the blue group participated (one boy and three girls). All children had their caregivers consent to partake in the study. The study followed Swedish Research Council’s (2017) ethics considerations and guidelines. Pseudonyms were used in this study. The teaching activity lasted approximately 45 minutes and was recorded by three stationary cameras and one hand-held digital video camera.

The recordings were transcribed using a multimodal approach in which talk, as well as activities, gestures and positions in the room were noted if important for constructing meaning in the specific situation.

Data analysis

The analysis comprised three stages, the first being descriptive and the second and third an analysis. Firstly, the preschool activities were described. Secondly, the empirical data material were analysed by using a thematic content analysis to inductively search for patterns (Braun & Clarke, 2006). This first analysis revealed four themes that came to describe programming in a preschool setting. Thirdly, the second analysis found three different themes that showed the relationship between the participants and the technological artefacts. Hence, the first and second step correspond to the first research question, while the third answers the second research question.

Results

To answer the first research question about how programming in a preschool setting, two perspectives are presented. The first is the description of the activities constituting the teaching sequence of programming. This is followed by four different themes that characterised what programming became in a preschool setting. Each theme is illustrated with excerpts from the empirical data.

Putting programming content into context

The preschool teachers and children had chosen the well-known tale of *The Three Little Pigs* as for the basis of their programming theme. Just after the first interview, the teachers introduced the storybook to the children. They read the book aloud, showed the pictures and used soft toys as props when they read and talked about the book. Moreover, the children used different materials to build the three houses. Yarn and wallpaper glue were used to build the straw house; the stick house was built from sticks that the children had collected in the woods. However, they struggled to get the sticks to hold together and so they attached them to a cardboard box. The third house, which in the story is built of bricks, was made by the children using red Lego bricks.

Before the teaching activity that was video-recorded, the preschool teachers had prepared printed and laminated copies of the pictures from the book. During the teaching activity, the children placed the pictures in the correct order to be able to retell the story of the book. Then, the teachers got the three houses and the children placed them on the floor. They positioned the soft toy pigs in the houses and retold the story together. After that, the children placed arrows on the floor to provide the wolf with directions to each house (figure 1). Next, the Blue-Bot® was introduced. The children tested how it worked and programmed it to walk from one side of the room, turn around, and return. However, at this moment the children had begun to lose their focus. The teachers encouraged the children to talk about what role the robot could play next time, but were unable to gain a consensus.



Figure 1. The children put arrows on the floor from the straw house (right corner) to the stick house (between the two children that sit on the floor) to indicate the route for the wolf.

What is programming in a preschool setting?

In the following sections, four different themes are presented that characterize what programming became in a preschool setting. These themes are built on what the teachers and children did and said.

Instructions

The preschool teachers discussed how programming includes the ability to express and follow *instructions*. The teachers' message was that the instructions must be precise, given in a correct order and clear to the receiver.

During the teaching activity, one of the preschool teachers, Sarah, asked the children to put all the pictures from the storybook in the same direction. She implicitly meant that the pictures should be facing the children (Figure 2a). However, the children interpreted the intention from the preschool teacher's view as depicted in figure 2b. One of the other preschool teachers,

Becca, noticed the misunderstanding between the teacher and the children and she said: “Now you weren’t clear enough”. She communicated the importance of giving accurate instructions.



Figure 2a. The teachers’ intended direction of the pictures.



Figure 2b. The children’s interpreted direction of the pictures.

This theme was rather prominent, both in the interviews, and in the teaching activity.

Sequence

In the teaching activity, one of the tasks was to place a sequence of pictures from the storybook in the correct order. The message that was communicated is that a sequence has a clear beginning, middle and ending, and follows a logical order. In the teaching activity, the sequence was illustrated by the order of the pictures from the storybook. The preschool teachers asked the children with which picture the story should begin and where on the floor it should be placed. The task was for the children to place the pictures in the correct order and thereby recreate the story (Figure 3).



Figure 3. The children put the pictures of the storybook in a sequence.

The sequence was clearly seen in the teaching activities but was not explicitly mentioned by the teachers during the interviews.

Bugs

The preschool teachers equated errors with bugs. In both interviews, the teachers talked about the bug as a typical programming concept that they want to include in the teaching activity. However, the concept appeared rather vague. For example, in the group interview, one of the teachers talked about a bug in terms of a rock in the way of the wolf trying to reach the three houses.

However, even though the teachers often mentioned bugs during the interviews, when teaching, they did not use the word bug. For example, the teacher Becca talked about doing a small trick, removing two pictures from the sequence the children had placed on the floor.

Becca: Yes, but I want to do a small trick if you are going to read the story. Then I will take away... [leans forward and removes two of the pictures]. Now you can try to read the story.

Andy: No! It will never work!

Becca challenged the children to think about the consequences of the missing pictures. This was a way for her to try to introduce the concept *bug* without using the term with the children.

Language

The preschool teachers talked about programming as a language. The language worked as the interface between the human and the machine. During the second group interview the teachers discussed how they introduced it to the children:

Becca: Aah, when Sarah pushes that button, she talks with the projector. We have started to introduce that as well.

During the teaching activity the teachers used the same way to talk about the buttons on the Blue-Bot®, as in the following sequence (figure 4):

Becca: This robot only talks one special language. It is the language of when we push on it [the buttons]. Then it knows what to do.

Furthermore, the teachers named this way of interacting with the robot as *programming*.



Figure 4. The children push the buttons on the Blue-Bot to make it follow the arrows.

Relation between human and technology

Targeting the second research question, the following themes aim to capture the relationship between human and technological artefact that was communicated through the teaching activities and the talk about programming. These themes could in some senses overlap with previous themes.

Anthropomorphism

The technological artefacts, the robot and the projector, acted as human (or animal) agents with human attributes. They could listen or did not understand a certain language. In the

following example, one of the children pushed the robot over the floor. However, this could damage the engines. Becca explained:

Becca: You know, you should never push... you always must lift him up. Otherwise he will hurt his wheels.

This way of talking about the technology in terms of human attributes was only seen in dialogue with the children.

Artefacts as gender coded

The technological artefacts were gender coded. In the example above, Becca talked of the robot in terms of “he”, even if it would be more appropriate in Swedish to entitle the robot as the gender-neutral pronoun “it”. Later, during the teaching sequence they discussed what name they should give the robot.

Technology as autonomous and as non-autonomous

When the teachers and children used the Blue-Bot®, it suddenly did not do what they thought that they had programmed it to do. When technology lives its own life, it is depicted as autonomous.

Becca: Follow that arrow. Which one [button] should you push?

Elsie: {Pushes the correct button, and then the start button, but the robot does not move}

Andy: Noo...

Becca: Has it gone to bed now?

In the example, Andy was devastated when the robot did not move. Becca tried to talk of it in terms of being tired. The malfunction was also explained in terms of low battery level. So even if the technology seems to live its own life sometimes, the overall message constructed in this teaching sequence was that the human is in control of the technology, since there were always logical explanations to why the robot did not work as intended.

Conclusions

Programming in the preschool in this study was situated within the context of a story book, *The Three Little Pigs*. Through the teaching activity, children were introduced to four different aspects of programming:

1. Programming involves the ability to express and follow *instructions*. Consequently, the instructions must be precise.
2. Coding is equivalent to a *sequence* that has a clear beginning, middle and ending, i.e., it follows a logical order.
3. All kinds of errors that occur are labelled as *bug*. However, the teachers do not use the word explicitly during the teaching activity.
4. Programming is communicated as a language that is in the interface between the human and the machine.

The relationship between humans and the technological artefacts was characterized in three different ways:

1. *Anthropomorphism*: the technological artefacts were endowed with human traits and behaviour, i.e. the projector can listen, or the robot does not understand a certain language.
2. *Artefacts as gender coded*: the technological artefact (the robot), was depicted as a male.
3. *Technology as autonomous and non-autonomous*: technological artefacts sometimes make their own “decisions” however humans generally control the technology.

In summary, in the preschool in this study, the programming activities and the robot were part of a wider context. The children were involved in language activities, collaboration, technological constructions, digital resources, story reading and narrating from a thematic approach. Consequently, the technology became a tool to achieve several learning objectives and the technology itself was not the main focus. We believe that the overall message of this teaching setting is that humans control and use technology to achieve specific purposes.

References

Axell, C. (2015). *Barnlitteraturens tekniklandskap – En didaktisk vandring från Nils Holgersson till Pettson och Findus*. [Technological landscapes in children’s literature – a didactic journey from Nils Holgersson to Pettson and Findus]. Doctoral Dissertation, Linköping University.

Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education* 72: 145-157.

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

Ellul, J. (1964). *The technological society*. New York: Vintage Books.

Janka, P. (2008). Using a programmable toy at preschool age: Why and how? *Workshop Proceedings of SIMPAR 2008*, International Conference on SIMULATION, MODELING and PROGRAMMING for AUTONOMOUS ROBOTS. Venice (Italy) 2008, November 3rd-4th.

Kazakoff, E. R., Sullivan, A., & Bers, M. U. (2013). The Effect of a Classroom-Based Intensive Robotics and Programming Workshop on Sequencing Ability in Early Childhood. *Early Childhood Education Journal*. 41(4): 245-255.

Kjällander, S., Åkerfeldt, A., & Petersen, P. (2016). Översikt avseende forskning och erfarenheter kring programmering i förskola och grundskola [Overview of research and experience of programming i preschool and compulsory school]. Swedish National Agency for Education. https://natverk.dfs.se/system/files/oversikt_programmering_i_skolan.pdf

Ministry of Education. (2017). Nationell digitaliseringsstrategi för skolväsendet [National strategy for digitalisation of the school system]. <https://www.regeringen.se/4a9d9a/contentassets/00b3d9118b0144f6bb95302f3e08d11c/nationell-digitaliseringsstrategi-for-skolvasendet.pdf>

Pannabecker, J. R. (1991). Technological impacts and determinism in technology education: Alternate metaphors from social constructivism. *Journal of Technology Education* 3(1).

Sullivan, A. & Bers, M. U. (2016). Robotics in the early childhood classroom: learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade. *International Journal of Technology & Design Education* 26: 3-20.

Swedish National Agency for Education. (2018). *Curriculum for the Preschool, Lpfö 18*. Stockholm: Norstedts Juridik kundservice.

Swedish Research Council. (2017). *Good Research Practice*. Stockholm: Swedish Research Council.

Vygotsky, L.S. (1962). *Thought and Language*. United States of America: MIT Press.

Vygotsky, L.S. (1978). *Mind in Society: the development of Higher Psychological Processes*. United States of America: Harvard University Press.

Waytz, A. (2014). The mind in the machine: Anthropomorphism increases trust in an autonomous vehicle. *Journal of Experimental Social Psychology* 52(3): 113-117.

Winner, L. (1977). *Autonomous Technology: Technics-out-of-control as a Theme in Political Thought*. Cambridge, Mass.: MIT Press.

A quantitative analysis of Maltese educational pathways and their impact on the take-up of the engineering profession.

Marc Anthony Azzopardi, Brian Zammit, Daniel Micallef, Daniel Buhagiar, Monique Borg Inguanez, Fiona Sammut, Alexia Pace Kiomall, Mario Cachia, Sarah Pulé.



Marc Anthony Azzopardi
Chamber of Engineers
Malta
marc.azzopardi@um.edu.mt



Brian Zammit
Chamber of Engineers
Malta
brian.zammit@um.edu.mt



Daniel Micallef
Chamber of Engineers
Malta
president@coe.org.mt



Daniel Buhagiar
Chamber of Engineers
Malta
daniel.buhagiar@um.edu.mt



Monique Borg Inguanez
Faculty of Science,
University of Malta
Malta
monique.inguanez@um.edu.mt



Fiona Sammut
Faculty of Science,
University of Malta
Malta
fiona.sammuto@um.edu.mt



Alexia Pace Kiomall
Malta University
Consulting
Malta
alexia.pacekiomall@muhc.com.mt



Mario Cachia
Malta University
Consulting
Malta
mario.cachia@muhc.com.mt



Sarah Pulé
Faculty of Education,
University of Malta
Malta
sarah.pule@um.edu.mt

ABSTRACT

The Maltese economy is growing at a brisk rate and surveys conducted by the Chamber of Engineers show that the demand for engineering professionals in the Maltese industry is very high. However, this contrasts sharply with the declining take-up of the engineering degree offered at the University of Malta (UM), which was until very recently, the only legally recognized Maltese route into the profession. Hence, reduced take-up of the engineering degree at UM may be associated with reduced take-up of the engineering profession. The objective of this study is to quantify the perceived decline in the take-up of the engineering profession and then quantitatively analyze the trends underlying the pathways taken by local students leading to the engineering profession in order to extract any patterns that may lead to new insights into the causes behind the perceived decline.

The results presented in this paper show that the popularity of subjects leading to the engineering degree, did not show any noteworthy signs of change throughout recent years until 2018. This while noting that the combination of Pure Mathematics and Physics taken at A'level remain an unpopular choice, albeit steady at around 6.8% of the corresponding Form 2 population. On the other hand, the number of students taking engineering, normalized as a percentage of the corresponding Form 2 baseline population, shows a steady decline as originally hypothesized. This was largely attributable to a decline in the relative popularity of this degree among students who have in fact obtained the necessary qualifications to follow the engineering course at (UM). This implies that, while the secondary and pre-university educational system should maintain focus on promoting STEM education in general, there needs to be a targeted campaign to attract students who are just about to make their choice in which course to enroll at University level.

Keywords: Maltese; Educational Pathways; Engineering Take-up; Quantitative Analysis

Introduction

The Economy thrives on the technological aptitude of countries. In the EU, Malta still lags behind most other countries in terms of Research and Development (R&D) expenditure in all sectors. However, it registered moderate growth rates in R&D expenditures (around 7%) over the 2005-2014 period. This is higher than countries such as Germany and Italy. The full statistics extracted from Eurostat data can be visualized in Figure 1. Moreover, as regards to high tech exports Malta showed the highest percentage exports in the electronics and telecommunications industry (EUROSTAT, 2018). Such trends, in favour of the technology industries, are clear signs of Malta's economic progress. Underpinning these are engineering professionals working in a variety of sectors. Is the current engineering work force adequate for the current needs? If so, will it continue to be sustainable? If not, why has this occurred and what can be done to pave the way for sustainability across Malta's major industries? All of these questions are rooted in the current educational system and how this is able to form engineering graduates from the very early stages of student development.

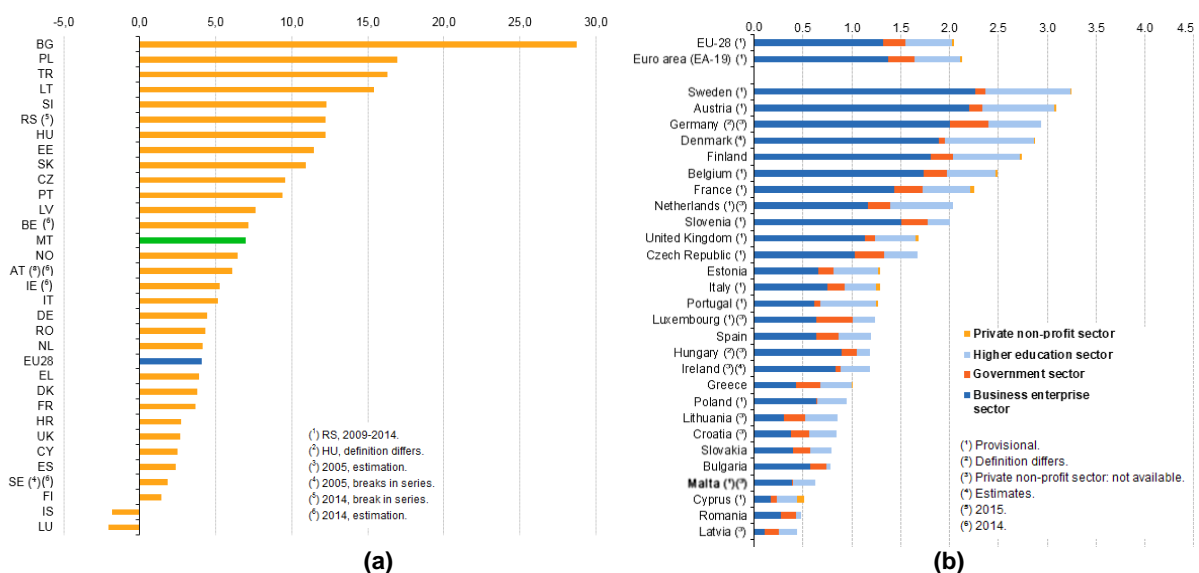


Figure 1 - (a) Average annual growth rate of R&D expenditure in business enterprises, 2005-2014. (b) Gross domestic expenditure on R & D by sector, 2016 (% relative to GDP) (EUROSTAT, 2018)

The hypothesis investigated in this research is to identify whether there is a real or perceived reduction in students taking up engineering as a professional career. While the absolute numbers show that there is an overall decline, there might be other factors which are causing the drop which are not related to the attractiveness of STEM subjects amongst students. One such reason could be associated with demographics, another could be related to structural changes to the educational system. To this effect, the Chamber of Engineers commissioned Malta University Consulting Ltd (MUC) to conduct a preliminary analysis on the statistical data that could be obtained from multiple sources. (Borg Inguanez & Sammut, 2019). Building on this, additional data, analysis and insights are being presented in this academic paper.

The overarching aim of the present study is therefore to use quantifiable metrics to establish possible causes for the decline in uptake of the engineering degree (B.Eng.) at the University of Malta (UM), where to date, this is the only legally recognized route leading to the engineering profession for Maltese residents.

The specific objectives of this work are listed hereunder:

- (i) To create a process diagram representing the typical educational pathway leading towards a career in engineering, showing student percentages at key decision points, from early secondary school (Form 2, also referred to as Year 8 (NCF, 2012)) to graduation from University. (see Figure 2). This will help identify the most promising avenue for increasing the popularity in engineering by identifying the most significant relative drop in potential B.Eng. candidates across this typical pathway.
- (ii) To identify any trends at various points along this pathway by comparing consecutive cohorts over the last ten years. This may shed some light on the perceived decline.

Background – The local context

The profession of engineering (mechanical or electrical engineers) in Malta is regulated under Engineering Profession Act (2017). According to article 3(2), an individual may qualify for the attainment of the warrant (license) to practice the profession only if he/she is in possession of an engineering degree from the University of Malta (UM) or equivalent. In this context, 'equivalence' can only be determined by the local authority known as the Engineering Board. Until the end of 2018, the only academic institution in Malta awarding degrees which qualify for the warrant was the University of Malta (UM). The second institution which awards degrees locally is the Malta College of Arts Science and Technology (MCAST) which however, up until 2018, did not qualify graduates for the warrant. Although changes are imminent, this was the situation in force throughout the period covered by the data. For this reason, over the period investigated, this study will attribute a reduced take-up of the engineering degree at UM to a reduced take-up of the engineering profession.

In view of this, the study presented here focuses on a historical picture which takes only into account graduates from UM. The structure of the Maltese educational system leading to the engineering profession for the period under study is shown in Figure 2.

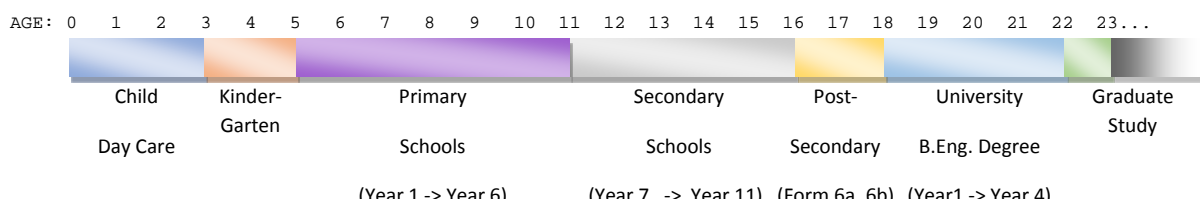


Figure 2: Structure of Maltese National Educational System in respect of Engineering, (NCF, 2012), showing the typical path taken by most students for the period under study.

Towards the end of Form 2, students ought to make their first choice of subjects amongst the sciences or languages. These students move on to do exams at O'level standard and attain the Secondary Education Certificate (SEC, 2017). This certificate is awarded with a pass at grade 5 or better in English Language, Maltese and Mathematics. The SEC certificate gives access to post-secondary education where students need to choose to opt for two A'level subjects and four subjects at an intermediate level. After two years of study, students sit for their exams which enable them to attain the matriculation certificate (MATSEC, 2018a). Once this certificate is attained, the student may then proceed to further his/her studies at tertiary level, specifically at UM. The entry requirements of the B.Eng. (Hons) degree (UM 2019a, 2019b) include Pure Mathematics and Physics at A'level with a grade of C or better. This has not changed over the course of this study.

Mathematics is a compulsory subject at SEC level and therefore all students attaining the SEC certificate become eligible to take Pure Mathematics at A'level which would then possibly lead to the choice of an engineering degree if the right grades are attained. The situation with Physics is however different. Some students are given the option (at Form 2) to avoid Physics altogether in secondary school. This choice effectively means that while they can attain their SEC certificate, it may be unlikely that they further their study of Physics at A'level. The second important choice that students need to take, if they decide to proceed with their tertiary education, is the choice of the two A'levels at post-secondary level. In this case, the students are generally well aware of the consequences of their choice to access the relevant courses at UM.

Students who have a Matriculation certificate including a grade C or better in Pure Mathematics and Physics can then choose from various degree courses in: Engineering (UM 2019a, 2019b), Architecture (UM 2019c), Science (UM 2019d) (specialization in Mathematics and Physics) and Computer Engineering (UM 2019e) besides the many others which have a subset of these requirements such as Education (UM 2019f) or Statistics (UM 2019g), and this is in addition to courses offered at other institutions.

The past years have seen an imbalance between the ever-decreasing number of students taking up engineering as a career path and the demand of engineers in industry. It was thus of interest to conduct a study in which the percentage number of students who took up subjects that lead to graduating with an engineering degree from UM is calculated at various critical points: Form 2, Form 5 Higher Secondary level, Further Education and finally, the successful completion of the engineering degree as shown in Figure 3.

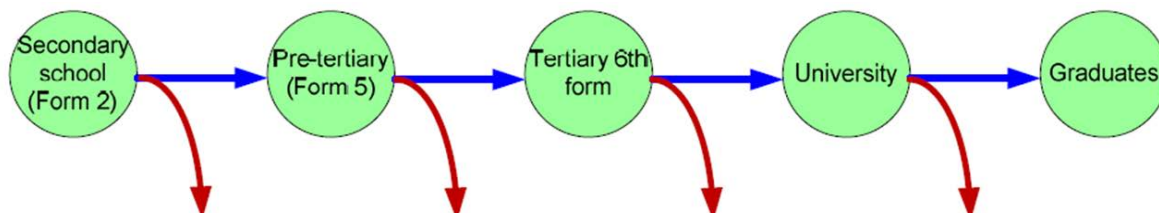


Figure 3: Key Decision points along the Maltese Educational Pathway for the Engineering Profession (Borg Inguanes & Sammut, 2019)

Methodology

Having identified the critical points, data was collected for the different stages for the period covering university academic years 2009/2010 – 2017/2018.

Form 2 data was obtained from the Ministry for Education and Employment, Form 5 and post-secondary data was obtained from the Matriculation and Secondary Education Certificate (MATSEC) Examinations Board, and the number of students choosing to pursue a degree in Engineering at UM and the number of engineering graduates from UM was obtained from the Registrar’s office at the UM.

Given that the aim of the study was that of tracking how the percentages of students change at the different critical points, percentages were worked out at the three critical points with respect to a common population, that is, the total number of students enrolled in Form 2 in all state, church and independent schools on the Maltese Islands.

If a student followed the academic path shown in Figure 3, from Form 2 to UM, a student enrolled in Form 2 in academic year 2007/2008, would have been enrolled in Form 5 in 2010/2011, in the second year of studies at post-secondary level in 2012/2013, entering UM in 2013/2014 and finally graduating from UM in academic year 2016/2017 assuming that he/she did not repeat one or more years and did not need to sit for examinations over multiple years. Statistical data related to these potential pathway extensions was not available. Moreover, from the data available, it was also not possible to cater for the possibility that non-Maltese nationals or immigrants started to attend Maltese schools after Form 2.

Results and Discussion

The perceived decline in uptake of the Engineering degree (B.Eng.) at the UM is clearly demonstrated by the time series of absolute student numbers registering for the degree as shown in Figure 4(a). The decline is weakly exponential and is observed along both the mechanical and electrical engineering sub-cohorts even after compensating for changes in births. The decline does not seem to be reflected in a corresponding increase in other courses sharing similar entry requirements, as can be seen in the total number of students enrolled in the main competitor courses shown in Figure 4(b).

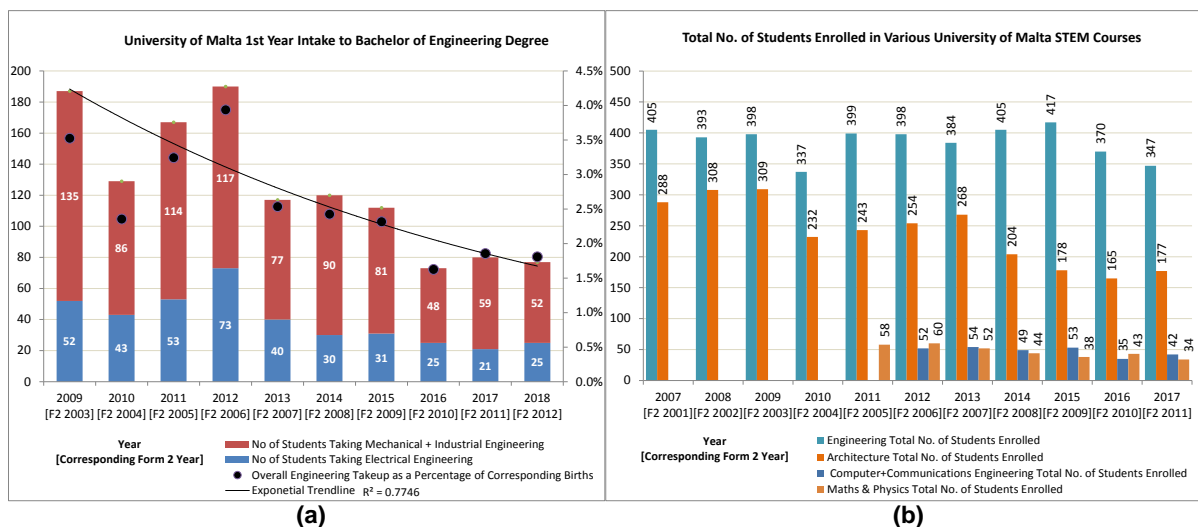


Figure 4: Trends in University of Malta Uptake of Engineering and other Degrees, (UM, 2018), (Borg Inguanez & Sammut, 2019)

Data compiled throughout the study is shown in Figure 5. Student numbers in Form 2 (Year 8) between 2007-2012 (Figure 5(b)) are used as a baseline for analyzing the number of students after key decision points throughout the educational pathway. The number of births is also included as reference (Figure 5(a)), and it can be observed that Form 2 student numbers actually increase with respect to students born 12 years before. This could be due to a number of possible reasons, for example, foreign students joining the Maltese cohort at a later stage, and some earlier scholastic years having a higher percentage of repeaters. The number of students at Form 2, rather than number of students born, is therefore used as the baseline in this study.

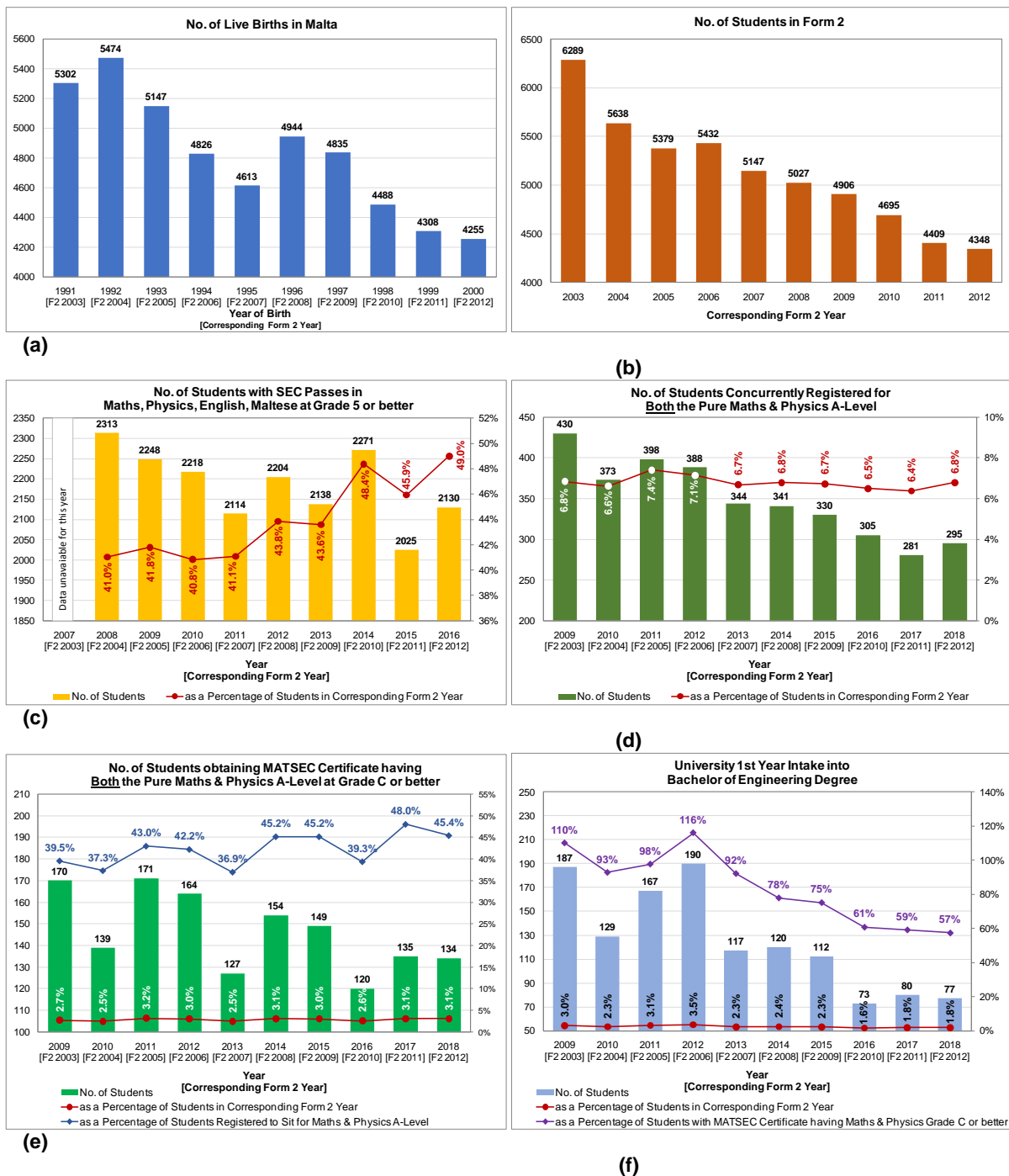


Figure 5: Student numbers and percentages at critical points across the educational pathway. (Borg Inguanetz & Sammut, 2019), (NSO 2010), (NSO 2018)

The next stage of the analysis considers the number of students who sat for the SEC exams 4 years later and obtained a pass in Mathematics (M), Physics (P), English (E) and Maltese (MT) with a grade of at least 5 in each of these subjects (Figure 5(c)). Over the period covered by the data this is considered as the most typical criterion for a potential candidate to choose Pure Mathematics and Physics at A'Level, and therefore become an eligible candidate for the B.Eng. degree at UM. Although student numbers vary across the years, it can be observed that when taken as a percentage with respect to the number of the students in the corresponding Form 2 year, the result is relatively stable at around 41% between 2008-2011, while exhibiting a slight uptrend across SEC sittings between 2011-2016. It is not clear whether this is due to improved examination *success rates* or due to an inflow of students after Form 2. One would need to compare the passes with SEC registrations.

The next key stage from the available data is when students register to sit for the MATSEC exams (Figure 5(d)). Here the key metric was considered to be the number of students registered for both the Pure Mathematics and Physics A'Level sittings.. Although a downward trend in absolute student numbers can be observed between 2011-2018, the computed percentage data seems to imply that across 2009-2018, the popularity of these subjects relative to the number of Form 2 students, remained fairly stable at around 6.6%. Scholastic data going further back could shed light on whether this relative proportion was sustained.

After registering for the respective A'level subjects, the next key metric is the number of students who obtain the MATSEC certificate with both Pure Mathematics and Physics at A'Level at Grade C or better (Figure 5(e)). Although other entry routes into the B.Eng. degree exist, these students are by far the most typical candidates. One can observe that the *success rate* for students, that is, students able to obtain at least grade C in both A'levels, with respect to those registered to sit for them, stands at an average of 42% for 2009-2018. However, one can note variations in this *success rate*, ranging from 36.9% in 2013 to 48% in 2017.

Interestingly, one can observe a slight uptrend in this percentage *success rate* over the same period during which a decline in the absolute number of successful students is observed. Therefore, one may be tempted to attribute this to an influx of students after Form 2. However, this trend is persistently observable in the separate time series for either Physics or Pure Mathematics A'levels, even when taken as a percentage of the registrations for these examinations, as shown in Figure 6. A number of factors could explain this, including: a whittled down syllabus, less-challenging examinations, more lenient marking or an improvement in student preparation for these types of examinations. More data and a deeper analysis would be required to reach any specific explanation.

A'level reform has often been suggested as a possible method to increase the pool of eligible students for engineering. However, one hypothesis that can be reliably refuted is that any decline (over 2009-2018) in the uptake of the engineering degree may be related with students having faced an increasingly harder time to make the grade in their A'levels over the same period. The opposite seems to be true.

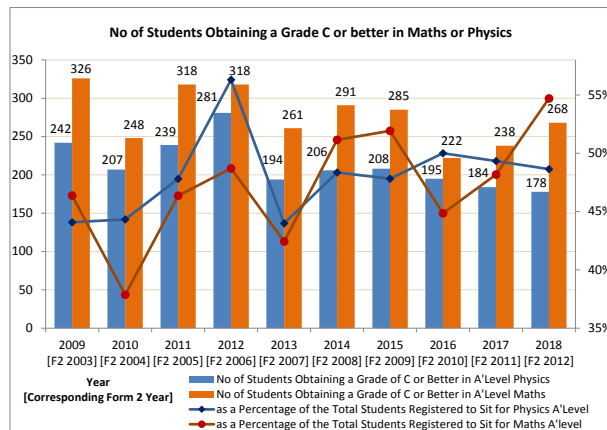


Figure 6: Separated Trends in Pure Mathematics and Physics A'level Success rates (MATSEC, 2018b)

Looking back at Figure 5(e), the computed percentage of students successful in obtaining a C or better in both Pure Mathematics and Physics A'levels relative to the baseline Form 2 cohort is relatively stable at around 2.9%. This percentage value is interesting, since it implies that out of 100 students in Form 2, only around 3 students will have successfully completed the (most typical) educational pathway leading to the UM degree in engineering.

Finally, Figure 5(f) shows the number of students entering the first year of the B.Eng. degree. The most pronounced drop in intake can be observed between 2012 and 2013, (after peaking in 2012) and it seems this number has continued to dwindle, with another sudden drop between 2015 and 2016 intakes. The Form 2 data does not reveal such sharp changes. However, as a correlation analysis will later confirm in Figure 8(d-f), the time series of Figure 6 and that of Figure 5(e) and Figure 5(f), also reveal a strong relationship between the number of successful A'Level candidates and the intake of the Engineering Degree. In particular, the 2012 surge (and 2013 drop) in engineering student intake may be explained by the coincident surge (and then drop) in the number of Physics A'level students obtaining a C or better. This cannot be explained by an increase in exam registrations, but is mainly due to an 8.5% jump (and then 12.4% drop) in the examination success rate.

On the other hand, an interesting metric in Figure 5(f) is the percentage of students having chosen the B.Eng. degree out of those with the most typical pre-requisite (MATSEC certificate with Pure Mathematics and Physics at A'Level at Grade C or better). This percentage moves closely with the number of students entering the degree, implying that at this crucial decision stage, the B.Eng. degree has indeed become a less popular option in the pool of eligible candidates leaving sixth form. This percentage value for 2016-2018 has dropped by around 50%, when compared to 2009-2012. The direct implication of this percentage on the number of potential B.Eng. students is further consolidated using correlation analysis.

The available data is also presented as a process using Sankey diagrams (Figure 7). These show how student numbers progress across the most typical educational pathway leading to the B.Eng. degree. One must note that minor inflows are possible at each node and these are not being accounted for due to data limitations. However, one conclusion that may be drawn from these diagrams is that student flow patterns have not changed very significantly over the years, and the low number of MATSEC (M+P) registrations remains the greatest stumbling block.

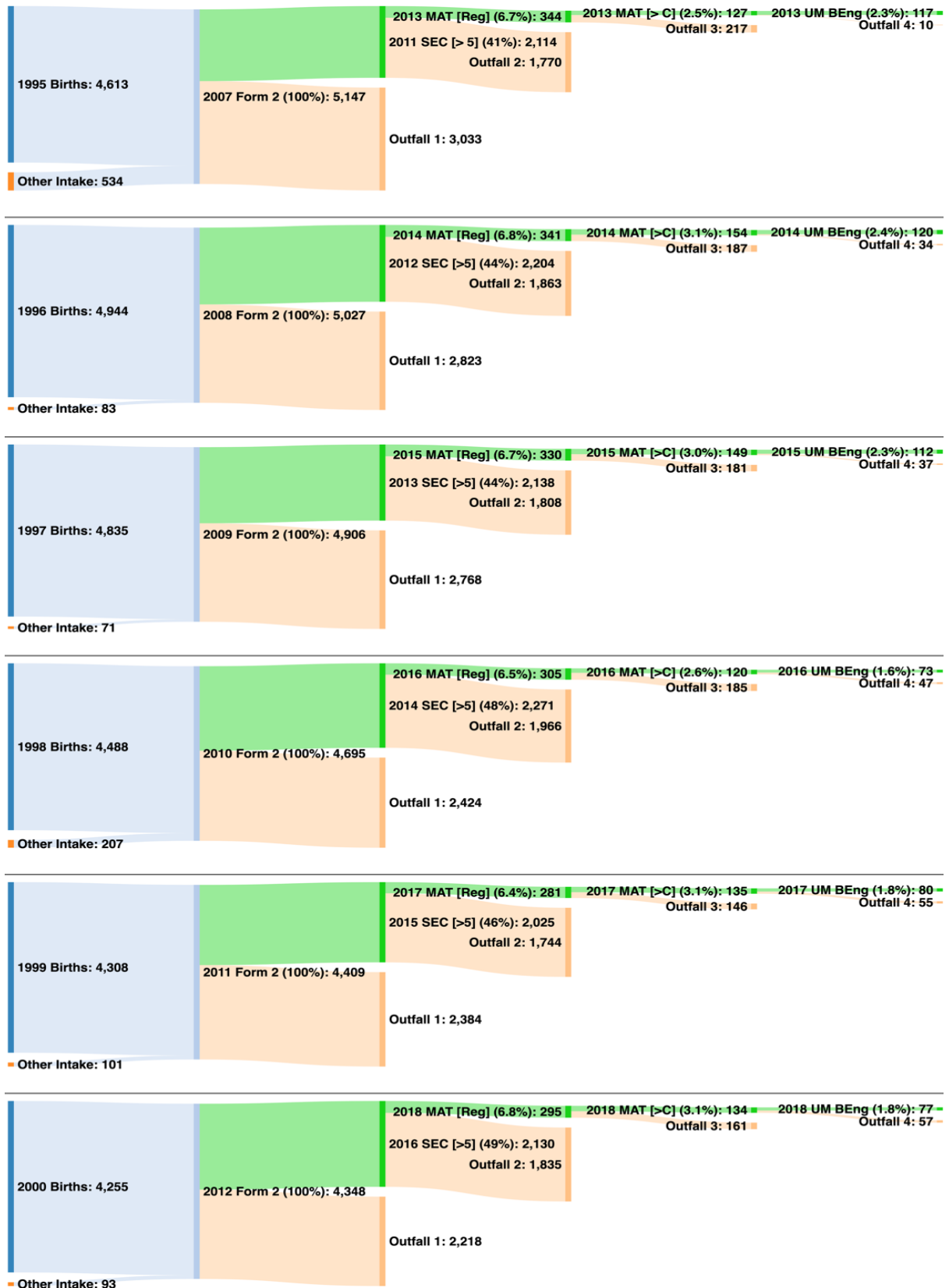


Figure 7: Sankey diagram representation of the most typical educational pathway leading to the B.Eng degree. "SEC [>5]" is the number of students who sat for SEC exams and passed Mathematics, Physics, English and Maltese, with a grade of at least 5 in each of these subjects; "MAT [Reg]" is the number of students who registered for Pure Mathematics and Physics A'levels; "MAT [>C]" is the number of students who obtained the MATSEC certificate with grade C or better in Pure Mathematics and Physics A'levels. "UM B.Eng." is the University of Malta Bachelor of Engineering degree course intake.

Results from correlation analyses are shown in Figure 8. This type of analysis was used to estimate the relationship (if any) between the selected variables. In the present study, the correlation was measured between the number of potential students at several key points along their educational path and the corresponding B.Eng. student intake. Given the small sample size being considered, caution should be exerted when interpreting these results or attempting to fit regression lines to model any perceived relationship.

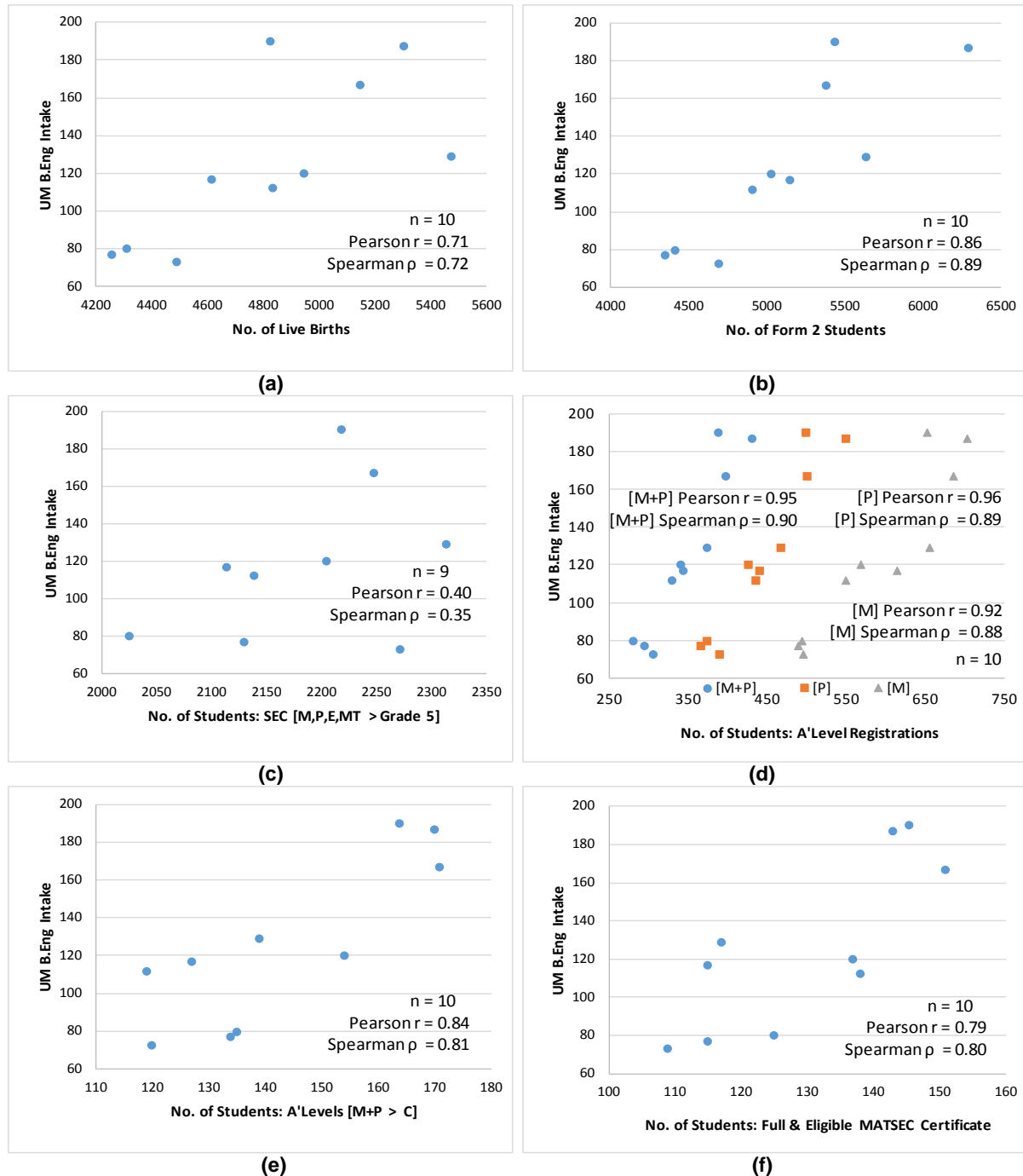


Figure 8: Results from correlation analyses of student numbers at key decision points in the most typical educational pathway leading to the B.Eng. degree. Pearson and Spearman correlation coefficients 'r' and 'p' are respectively provided next to each chart. The figures correspond to the 2009-2018 B.Eng. intake. "SEC [M,P,E,MT > Grade 5]" is the number of students who sat for SEC exams and passed Mathematics (M), Physics (P), English (E) and Maltese (MT), with at least grade 5 in each of these subjects; "A'Level Registrations" is the number of students who registered for Pure Mathematics and Physics A'levels concurrently [M+P] or separately [M], [P]; "A'Levels [M+P > C]" is the number of students who obtained a grade C or better in both Pure Mathematics and Physics A'levels when taken concurrently.

The Pearson coefficient 'r' measures linear relationships, while the Spearman coefficient 'ρ' is more general in that it measures monotonic relationships which are not necessarily linear. For Figure 8(a), $r = 0.71$ and $\rho = 0.72$, which indicates a positive correlation between demographics (specifically, the number of live births) and the B.Eng. intake. This is expected, but the effect is however overshadowed by the stronger relationship to the Form 2 population, as shown in Figure 8(b) ($r = 0.86$, $\rho = 0.89$). On the other hand, Figure 8(c) shows very weak correlation ($r = 0.40$, $\rho = 0.35$) with the number of students obtaining the four SEC examinations as defined in the figure.

Student registrations for the combination of Pure Mathematics and Physics, exhibit the highest correlation with B.Eng. uptake as shown in Figure 8(d) ($r = 0.95$, $\rho = 0.90$). The latter signifies a rather strong intention to follow engineering studies among students registering to sit for these prerequisite A'levels. This is also apparent from the separated Pure Mathematics ($r = 0.96$, $\rho = 0.89$) and especially Physics ($r = 0.92$, $\rho = 0.88$) registrations.

However, following A'level examinations, this high correlation decreases somewhat among students who actually obtain the necessary grades, as shown in Figure 8(e) ($r = 0.84$, $\rho = 0.81$), and decreases slightly further among those who obtain the full MATSECC certificate, as shown in Figure 8(f) ($r = 0.79$, $\rho = 0.80$).

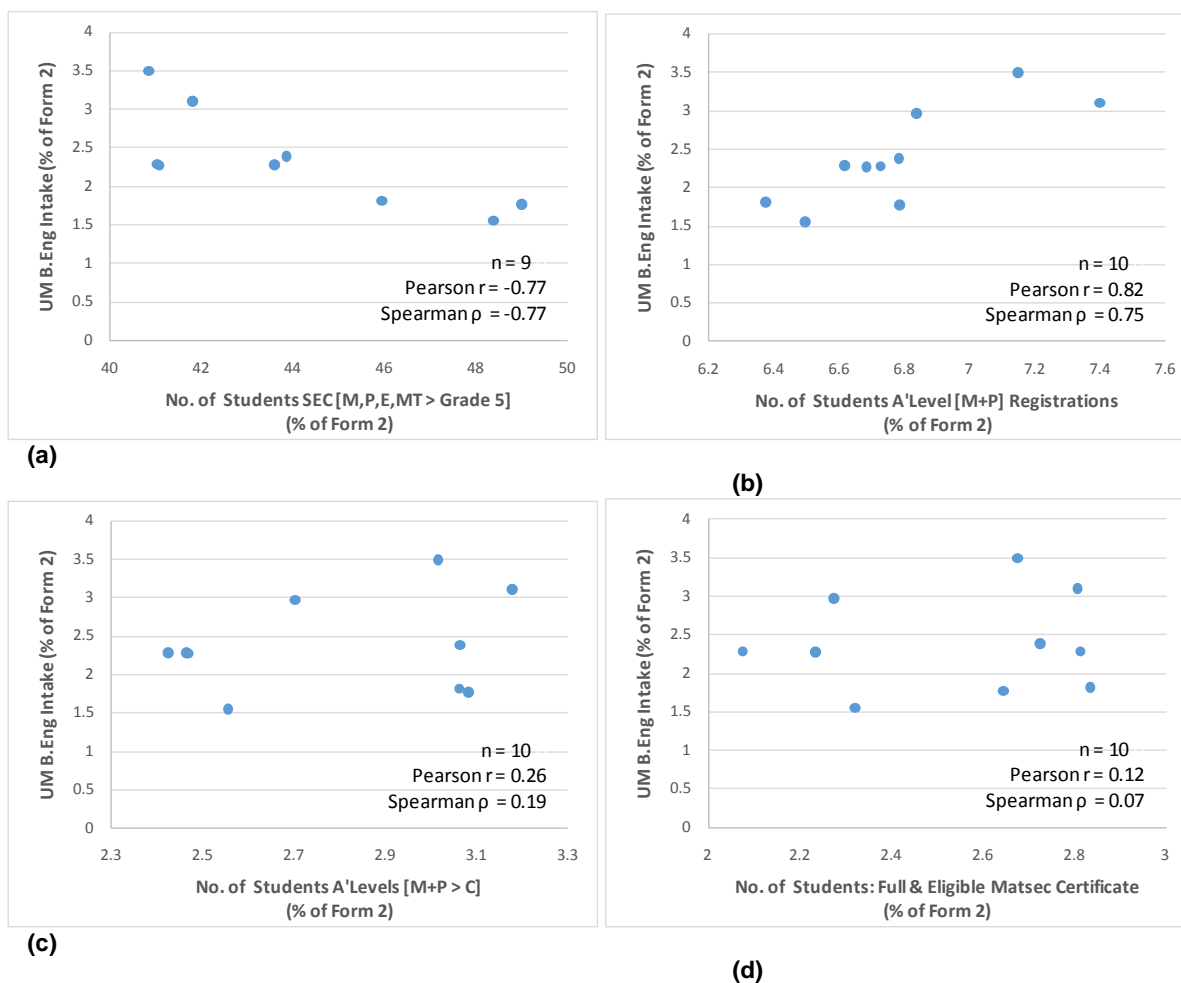


Figure 9: Correlation analyses of Figure 8 (c),(d),(e) and (f) repeated when student numbers are taken as a percentage of the corresponding Form2 population.

To better explain the relationships between selected variables at the various nodes, the data was further processed and the correlation analyzed once again. To this effect, student numbers at each decision point were referenced to the corresponding Form 2 population. This allowed us to investigate to what extent is the large decline in the Form 2 population, as depicted in Figure 5(b), affecting the resulting correlations and whether the initial correlation results presented above are retained after this adjustment is introduced.

The results of this further analysis are shown in Figure 9, where the variables on both axes are now represented as a percentage relative to the corresponding student population in Form 2. The results immediately suggest that the large decline in Form 2 population is in fact masking some underlying trends that are now evident in Figure 9.

Specifically, Figure 9(a) indicates a strong negative correlation ($r = -0.77$, $\rho = -0.77$) between the percentage B.Eng. intake and the percentage of students obtaining the four SEC examinations as defined in the figure. This result is in full agreement with the time series plots of Figure 5(c) and 5(f) in which, despite the improving percentages in SEC passes, the B.Eng. percentage intake for the years being considered was still in decline. Therefore, it seems that the SEC examination success rates are not determining the eventual B.Eng. intake, and are perhaps blocking the path for students who may wish to follow engineering or significantly altering the ambitions of those who do make the grade.

The slightly diminishing correlation values at the three decision points shown in Figure 8(d), 8(e) and 8(f), become much more noteworthy when viewed as a percentage value of the corresponding Form 2 population. Indeed, Figure 9(b-d) show a correlation that ranges from strong ($r = 0.82$, $\rho = 0.75$) to very weak ($r = 0.26$, $\rho = 0.19$) to no correlation ($r = 0.12$, $\rho = 0.07$) respectively along these three decision points. In other words, this disconcerting finding means that the B.Eng. percentage intake is very well described by the percentage of students registering for the relevant A'Level subjects but poorly described by the percentage of those obtaining the relevant A'Levels or relevant MATSEC certificate. One may again argue that these examinations are filtering away, or dissuading a good proportion of students who might have had engineering ambitions. It is also possible that students become aware of other career alternatives once the relevant certificate is obtained. One could also add that patterns obtained over a larger number of years would give a much better indication of any actual trends present in the data. However, these conclusions seem to be in agreement with the perceived situation.

Conclusions

In this paper, student numbers at various key decision points along the Maltese education system were used to create a number of process diagrams that represent the typical education pathway from Form 2 to the B.Eng. degree at the University of Malta (UM). The data corresponding to the B.Eng. intake 2009 - 2018 was then used to:

- 1) Check whether the perceived decline in B.Eng. uptake is only a result of changing demographics.
- 2) Identify any underlying relationships between the B.Eng. intakes with respect to the key decision points along the educational pathway.

A main challenge throughout this work was the considerable difficulty in acquiring comprehensive data both from public and private authorities. Such data will be crucial for

increasing the sample size hence the confidence in these findings. Despite these limitations the following main conclusions may be drawn:

1. The number of students *registering* for the combination of both Pure Mathematics and Physics at A'level is quite steady at a low 6.8% of the total student population from Form 2. These numbers can certainly be improved by enticing more students towards Pure Mathematics and Physics at an early age, especially at key decision points.
2. Examinations could be posing a stumbling block for a considerable number of students wishing to follow engineering studies at UM. However, any arguments to lower the bar for students must be weighed against the fact that engineering does require a certain technical aptitude, effort and commitment and that these examinations may be performing an important *reality check* or filtering function.
3. The percentage of students (adjusted to the corresponding population in Form 2) *obtaining* the necessary qualifications (MATSEC Certificate with Pure Mathematics and Physics at grade C or better at A'level) to be eligible to follow the engineering degree, has been rather uniform with a slight increase over these past six years.
4. The UM engineering degree course has been steadily attracting less and less students in percentage terms (with respect to Form 2, and more notably, to the eligible candidates with a MATSEC certificate). In fact the percentage number of these potential students has dropped by almost half over the past six years, mainly in two sharp declines occurring at the 2012-2013 and 2015-2016 intervals.
5. A'level success rates (relative to those sitting for Pure Mathematics and Physics examinations) were not a contributor towards the decline in the take-up of the University of Malta engineering degree over the years investigated. If anything, A'level success rates have been increasing over the years we have observed.

The latter two conclusions indicate that the attractiveness of embarking on an engineering career through UM is diminishing at a time when the Maltese economy is experiencing a rapid expansion (Economic Forecast for Malta, 2019). Moreover the decline is occurring at the stage when students are actively choosing their career path at university entry, which indicates that there may be a conscious avoidance of the engineering degree at UM rather than a lack of eligible candidates. In addition, the UM may be inadvertently facilitating a shift towards the ever-expanding range of degrees within the STEM sector which could be offering graduates more attractive remuneration through alternative career opportunities. Regrettably to the engineering community, this increase in demand for students in the STEM sector is not being matched proportionally on the supply side. From the data that was available, it does not appear that the courses with traditionally similar entry requirements (to engineering) within UM itself can fully account for this decline. So it is quite possible that students are indeed venturing wider or choosing not to further their studies beyond the A'levels, perhaps because the buoyant job market is offering good prospects with lower qualifications.

That said, it also remains unclear whether this decline is compensated by a commensurate increase in the take-up of engineering studies outside of UM. In particular, courses offered at MCAST are likely to increase their competitiveness once they are reformed and formally recognized by the state as leading towards the profession. However, it is yet unclear in what measure (if any) these may have contributed to the decline already seen at UM over the past decade.

On the other hand, given the positive correlation of B.Eng. intake with birth statistics, the recent surge in births (Malta Independent, 2018) could eventually compensate for this decline in absolute terms. While we should clearly do more to promote the attractiveness of STEM in

general terms, in order to entice students at an early age in order to push up the percentages later on, it is also clear that a lot of work needs to be done to re-popularize the UM engineering degree at the critical stage when pupils are choosing their career path at university level.

The reasons for these observed phenomena will be considered in a separate survey study which will address questions about the reasons of why students are opting for other careers rather than engineering.

References

Borg Inguanez, M. & Sammut, F., Pace Kiomall, A. (Ed.), Cachia, M. (Ed.). (2019). Data Analysis and Data Processing Report: Engineering Education in Malta Paving The Way for Future Industry, Commissioned by the Malta University Consulting Limited, on Behalf of The Chamber of Engineers. Retrieved from: <http://coe.org.mt/images/stories/core/mucreport2.pdf>

Economic Forecast for Malta (2019). European Economic Forecast. Winter 2019, European Commission, Luxembourg: Publications Office of the European Union, Retrieved from: https://ec.europa.eu/info/sites/info/files/economy-finance/ip096_en.pdf, pp. 22

Engineering Profession Act, (2017). Chapter 321 of the Laws of Malta, Malta: Ministry for Justice, Culture and Local Government, Retrieved from: <http://www.justiceservices.gov.mt>

EUROSTAT (2018). R&D expenditure of the European Union (EU), ISSN 2443-8219, Luxembourg: Statistical Office of the European Union, Retrieved from: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=R_%26_D_expenditure.

Malta Independent, (2018). Number of births in Malta skyrocket between 2008 and 2017, The Malta Independent Online, 22nd May 2018, Retrieved from: <http://www.independent.com.mt/articles/2018-05-22/local-news/Number-of-births-in-Malta-skyrocket-between-2008-and-2017-6736190315>

MATSEC (2018a). Matriculation Examination Regulations, MATSEC Examinations Board, Retrieved from: https://www.um.edu.mt/matsec/regulations/mc_regulations

MATSEC (2018b). Statistical reports. Retrieved from the MATSEC website <https://www.um.edu.mt/matsec/reports/statisticalreport>.

NCF (2012). A National Curriculum Framework for All, Ministry of Education and Employment, Malta: Salesian Press.

NSO (2010). Children, Malta: National Statistics Office, Retrieved from: https://nso.gov.mt/en/publicatons/Publications_by_Unit/Documents/C1_Living_Conditions_and_Culture_Statistics/Children_2010.pdf

NSO (2018). Education and Information Society Statistics, Malta: National Statistics Office, Retrieved from: https://nso.gov.mt/en/publicatons/Publications_by_Unit/Pages/C4-Education-and-Information-Society-Statistics.aspx

SEC (2017). Secondary Education Certificate (SEC) Regulations, MATSEC Examinations Board, Retrieved from: https://www.um.edu.mt/matsec/regulations/sec_regulations

UM (2018). Student Statistics by Faculty / Institute / Centres / Schools and Course, Student Numbers, University of Malta, Retrieved from: <https://www.um.edu.mt/registrar/factsAndfigures/studentnumbers>

UM (2019a). Bachelor of Engineering (Honours) in Mechanical Engineering, University of Malta, Course Information, Retrieved from: <https://www.um.edu.mt/courses/overview/UBENGHMECFT-2019-0-O>

UM (2019b). Bachelor of Engineering (Honours) in Electrical and Electronic Engineering, University of Malta, Course Information, Retrieved from: <https://www.um.edu.mt/courses/overview/UBENGHELEFT-2019-0-O>

UM (2019c). Bachelor of Science (Honours) in Built Environment Studies, University of Malta, Course Information, Retrieved from: <https://www.um.edu.mt/courses/overview/UBSCHBENFT-2018-9-O>

UM (2019d). Bachelor of Science (Honours) in Mathematics and Physics, University of Malta, Course Information, Retrieved from: <https://www.um.edu.mt/courses/overview/UBSCHMATPHY-2019-0-O>

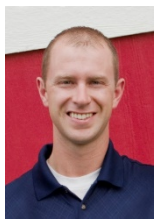
UM (2019e). Bachelor of Science (Honours) (Computer Engineering), University of Malta, Course Information, Retrieved from: <https://www.um.edu.mt/courses/overview/UBSCHICPEFT-2019-0-O>

UM (2019f). Bachelor of Science (Honours) in Technical Design and Technology, Course Information, University of Malta, Course Information, Retrieved from: <https://www.um.edu.mt/courses/overview/UBSCHTDTFT-2018-9-O>

UM (2019g). Bachelor of Science (Honours) in Mathematics and Statistics and Operations Research, Course Information, University of Malta, Course Information, Retrieved from: <https://www.um.edu.mt/courses/overview/UBSCHMATSOR-2019-0-O>

First, Last, Elsewhere ... Positioning Adaptive Comparative Judgment in the Design Learning Experience.

Scott Bartholomew, Liwei Zhang, Esteban Garcia Bravo, Greg J. Strimel



Scott R. Bartholomew
Purdue University
USA
sbartho@purdue.edu



Liwei Zhang
Purdue University
USA
zhan1128@purdue.edu

ABSTRACT

Adaptive Comparative Judgment (ACJ), has gained traction as a highly-reliable and effective method of assessment for open-ended design problems. The outputs of ACJ, which include a rank order of assessed items and a collection of judge comments, have been used formatively to improve student learning and design abilities (Bartholomew, Strimel, & Yoshikawa, 2018; Seery & Canty, 2017). However, little is known about how using ACJ as a primer for student learning may impact students design experiences and achievement. Placing ACJ at the beginning of a design activity—as opposed to the end (Kimbell, 2012) or in the midst (Bartholomew, Zhang, Garcia-Bravo & Strimel, 2019)—may help students in a variety of ways from brainstorming to expanding creativity or fostering new ideas and approaches. Therefore, this study investigated the implications of engaging students in ACJ at varying points of the design process. Students enrolled in three sections of a university-level graphic design course participated in this study by engaging in ACJ of peer work at varying points of an assignment. Student work for both the first and last assignment, from all three sections, was assessed by a panel of experts following the conclusion of the course. The results from the assessment of work for the first assignment were used to establish comparability among sections and results from the assessment of work for the final assignment were used to investigate the differences, if any existed, among treatment groups. Further, all students were surveyed to elicit their perceptions of using ACJ and their responses were used to further explore the results. Our findings suggest that using ACJ formatively may be a more impactful utilization than the original intended use (e.g., as a summative assessment tool). Student’s comments suggest they value the exposure to new ideas, the opportunity to compare peer work, and the feedback received during the process.

Keywords: Adaptive Comparative Judgment, Design Assessment, Formative Assessment, Graphic Design

Introduction

Design learning requires learners to develop skills of creativity, communication, and problem-solving – all skills which are difficult to teach and formatively assess with validity, reliability, and feasibility (Bartholomew, 2017; Pollitt, 2012). Adaptive comparative judgment (ACJ) has been used in formative assessment of creative graphic design classes to facilitate peer review and improve students' design abilities and critical thinking skills (Bartholomew, et al., 2018, 2019). However, it has not yet been studied how different uses of ACJ (e.g. at different stages of design process, or with a different frequency) can make impact on student learning (Bartholomew & Yoshikawa, 2018). This research examined the implications of engaging students in ACJ at varying stages (brainstorming & revising) of the design process during a university-level graphic design course.

Research Questions

1. What are the impacts on student achievement when using ACJ to inform design decision-making?
 - a. What is the relationship between frequency of ACJ use and student achievement?
 - b. What is the relationship between timing of ACJ use and student achievement?
2. What are student perceptions of using ACJ as a formative assessment and learning tool?

Design Learning and Graphic Design Projects

Design studio, a technique where a group of students work on visual design projects while receiving personalized instruction through informal communications with peers and teachers (Neumann, 1988; Barrett, 2000) has been increasingly used in graphic design education at college level (Hokanson, 2012). In these scenarios students are often introduced to design principles for visual communication, and then allowed to create and experiment as they complete graphics assignments (Bartholomew, et al., 2019). The use of design projects in this research emphasized investigation into the implications of using ACJ to impact students' understanding of design principles and enrich students' learning (Findeli, 2001).

Formative Assessment in Design Learning

Formative assessment in design education is a pedagogical approach that can be used in engaging students in the process of evaluating the success and failure of a design (Öztürk & Türkkän, 2006) to develop understanding of "good" design (Ehmann, 2005). The majority of assessments techniques for design projects compare a design with a predetermined standard, such as criteria, or use a rubric (Markham, 2011; Panadero & Jonsson, 2013). However, there are concerns about the reliability of using criteria-based assessments with students as assessors may lack of professional training and an understanding of the design criteria (Heldsinger & Humphry, 2010; Kimbell, 2012).

Moore and Fitz (1993) recommend evaluating digital graphic design projects according to accepted Gestalt principles (e.g., figure-ground segregation, symmetry, closure, proximity, good continuation, and similarity). This process involves "Gestalt," which relies on a holistic impression created by an image when first viewed. Gestalt is followed by the cognitive process of breaking this first impression of the image down into several other areas for assessment and score allocation (Moore & Fitz, 1993).

Adaptive Comparative Judgment

One form of holistic assessment—adaptive comparative judgment (ACJ)—rose from a CJ model proposed by psychologist Louis Thurstone (Thurstone, 1927). While the history of both comparative judgment (CJ) and adaptive comparative judgment (ACJ) have been documented extensively elsewhere (Kimbell, 2012; Pollitt, 2004, 2012), a brief introduction to this approach may be beneficial in terms of framing this research endeavor. ACJ, as an approach to assessing items, relies on viewing pairs of items and choosing which item is better. This comparison-based approach is intentionally different from other approaches (e.g., rubrics) which often involve assigning value-laden scores to items based on a rubric, standard, or criteria. As assessment approaches both CJ and ACJ have consistently demonstrated high levels of reliability – this is due, at least in part, to the differences in this approach which rely on a comparison rather than a value-laden judgment. Pollitt (2004) demonstrated the potential for improving reliability through a reliance on the principle that human beings are much more reliable at making comparative judgments than subjective judgments. ACJ builds on the reliability gains through comparative judgment—inherent in CJ—through the addition of an algorithm which intentionally pairs similarly assessed/ranked items and expedite the refining process to produce the output of a rank order and reliability coefficient in a more efficient manner (Pollitt, 2012, 2015).

In an ACJ setting, a collection of items (e.g., essays, portfolios, or designs) could be uploaded to an online platform (e.g., *CompareAssess*) for judgment. During the ACJ experience a judge, or judges, would view pairs of items and identify which item was better. Their decision for each judgment would be based on their own expertise, experience, and an identified “holistic statement” for making decisions (Kimbell, 2007; Pollitt, 2004, 2015). Following each judgment decision a new pair of items would appear on the screen for comparison. This process is repeated, with pairings of items, until a predetermined stopping point or until an identified reliability level has been reached.

Although originally designed as an assessment tool—focused on summative settings for use with professional judges—the positive effects of utilizing ACJ as a learning tool for students through formative peer assessment have been documented in recent work (Bartholomew, et al., 2019; Bartholomew, et al., 2018; Seery, Buckley, Doyle, & Canty, 2016). Jones and Alcock (2013) implemented peer assessment and feedback in higher education through the use of ACJ and reported that participating in ACJ, as a formative feedback tool, afforded students the opportunity to engage in peer feedback which helped students to feel more confident and competent in their final product (Jones & Alcock, 2013; Walker, 2015). Bartholomew, et al. (2019) found that students enjoyed using ACJ for formative peer assessment and feedback and students engaged in ACJ made gains relative to their peers in terms of performance on graphic design projects. Additional higher education studies have found that students react well to having ACJ as a formative peer assessment as it focuses on assessing the student work as a whole and facilitates improvement across the entire body of students (Seery et al., 2016; Canty, Seery, Hartell, & Doyle, 2017).

While using ACJ for formative peer design assessment has been studied across grade levels (Bartholomew & Yoshikawa, 2018) there has not been a consistent approach to when the ACJ formative experience happens. For example, Seery et al. (2016) utilized ACJ prior to each subsequent assignment, Bartholomew et al. (2018) utilized ACJ in the midst of a design assignment and Bartholomew et al. (2019) situated ACJ both prior to beginning, and in the midst of, an assignment. While the benefits of using ACJ for formative peer design assessment are documented, an understanding of where and when ACJ should be situated in a design experience is not well defined.

Methodology

Context. This study took place in an introductory level computer graphic design course at a large public university in the midwestern United States. At this university, this course is mandatory for all undergraduate students majoring in computer graphics technology to take. In this course, students learn the basics of graphic design principles through creating digital images with computer software, such as Adobe Photoshop, Illustrator, and After Effects.

Participants. A total of 158 students and six instructors participated in the study. The six instructors were the ones who taught the three sections at the time of study. Among the participating students, there were 86% freshman students, 9% sophomore students, 4% junior students, and 0.9% senior students enrolled, with 50% females and 50% males. The student participants were enrolled in three class sections taught by different instructors. Students were organized into three groups, by their section enrolled, and participated in one or two ACJ sessions as they were working on the first design project in the course. Further, a survey reflecting about their ACJ experience was distributed to all students.

Design Projects. ACJ was utilized during the first and fourth project in this course. Students started with the first project which was a simple and consists of using basic geometric shapes and different colors to apply the principles of design and create an abstract image. The fourth project was, however, more technically and conceptually complex, where students were asked to design an infographic that communicates large amount of data and information through an image. A total of 152 Project 1 and 74 Project 4 were collected in this study.

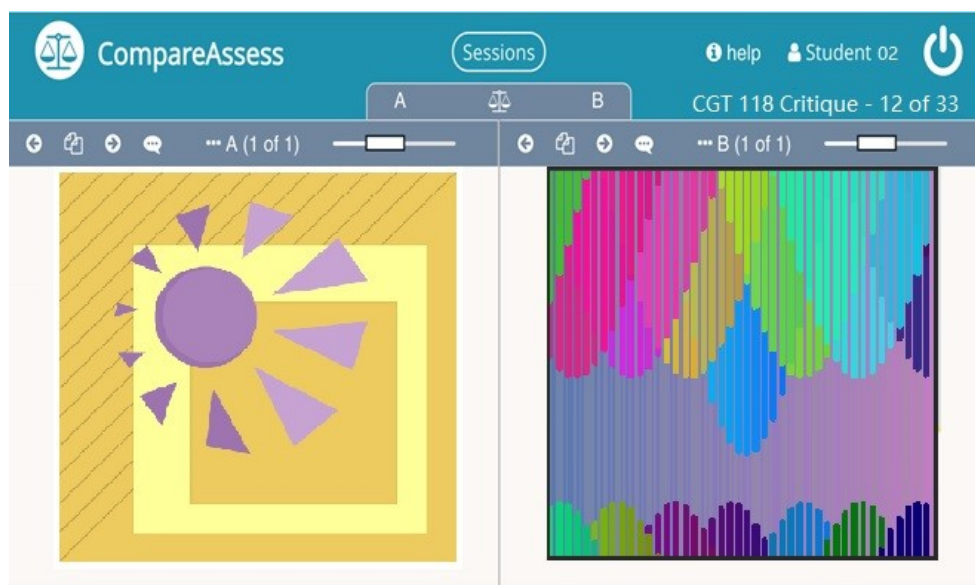


Figure 10. *CompareAssess* Interface

ACJ. *CompareAssess* (Digital Assess, 2018), a commercialized online ACJ platform, was used in this study (See Figure 1). Students participated in ACJ sessions as judges—comparing peer work and providing comments related to their decisions—at two different points in a design project: during the process of brainstorming and during the process of revising Project 1 (see Table 1). The student group B participated in ACJ at the beginning of their design process with student designs from past year immediately after the project was assigned. Student group M participated as judges through ACJ in the middle of the design process immediately following the submission of their first draft. These students were allowed one week to revise based on feedback from ACJ sessions and re-submit their final design for

grading. Student group T engaged in ACJ as judges two times – once prior to the assignment and once in the middle of the design process.

Table 1.

Student Groups

Group Name	Class Size	ACJ Intervention
B	53	ACJ at the beginning
M	52	ACJ in the middle
T	53	ACJ at the beginning & in the middle

After students' ACJ sessions, a survey was distributed to all three sections to collect students' perceptions of using ACJ as a new form of peer formative evaluation. A total of 100 responses were collected. Survey questions were derived from a similar instrument used with students and ACJ (Bartholomew et al., 2019). Additionally, following the ACJ sessions for students in group B, M, and T a group of six instructors completed two additional ACJ sessions, one with Project 1 submissions from all three classes to establish the comparability of three student groups, and another for Project 4 to investigate the similarities and differences in student performance between sections.

Findings

RQ1: What are the impacts on student achievement when using ACJ to inform design decision-making?

Student projects were collected, from the three different sections included, and compared in an ACJ session with the instructors as judges. The researchers conducted a one-way ANOVA to investigate the student achievement – as measured through the parameter values generated from instructors' ACJ session. No significant difference ($p=0.474 > 0.05$) was founded in parameter values of students' design projects (Project 1) from the three groups suggesting comparability between the sections.

Further, to investigate the potential impact of different ACJ timing on student achievement the parameter values from the ACJ session with Project 4 submissions were investigated with a one-way ANOVA. There was no significant difference ($p=0.541 > 0.05$) found in the parameter values among the three groups in Project 4.

Table 2.

ACJ Results: Parameter Values

GROUP	PROJECT 1		PROJECT 4	
	Mean	SD	Mean	SD
B	-0.126	1.14	0.286	1.76
M	-0.016	1.07	0.047	1.97
T	0.142	1.15	-0.259	1.71

To further analyze if the different frequency and timing of ACJ use would affect student achievement, the researchers conducted t-test between groups.

RQ1a: What is the relationship between frequency of ACJ use and student achievement?

Based on the t-test results between student group who did ACJ once (Group B and M) and those who did ACJ twice (Group T), there was no significant difference (B vs T: $t(49) = 1.14$, $p = 0.26$; M vs T: $t(37) = 0.57$, $p = 0.58$) found in student achievement with different frequencies of ACJ use.

RQ1b: What is the relationship between timing of ACJ use and student achievement?

There was no significant difference ($t(39) = 0.42$, $p = 0.68$) found between the student group who did ACJ at the beginning of project (Group B) and in the middle of project (Group M) indicating no significant difference in student achievement with different timings of ACJ use.

To further investigate student experiences, 13 Likert-scale questions (See Appendix) were distributed to students. The results of the questions emphasizing students' ACJ experience are listed in Table 3 (Note: responses to only five questions were used in our initial analysis due to the nature of the research design in which students in the control group answered questions regarding "feedback" which was obtained from their instructor directly while students in the experimental group referred to "feedback" received through ACJ). Overall our analysis of student responses to the questions demonstrated that students enjoyed the ACJ process and did not believe the ACJ comparison process was difficult to complete. Students found ACJ helpful to their learning through being a judge and making comparisons—regardless of the timing of ACJ.

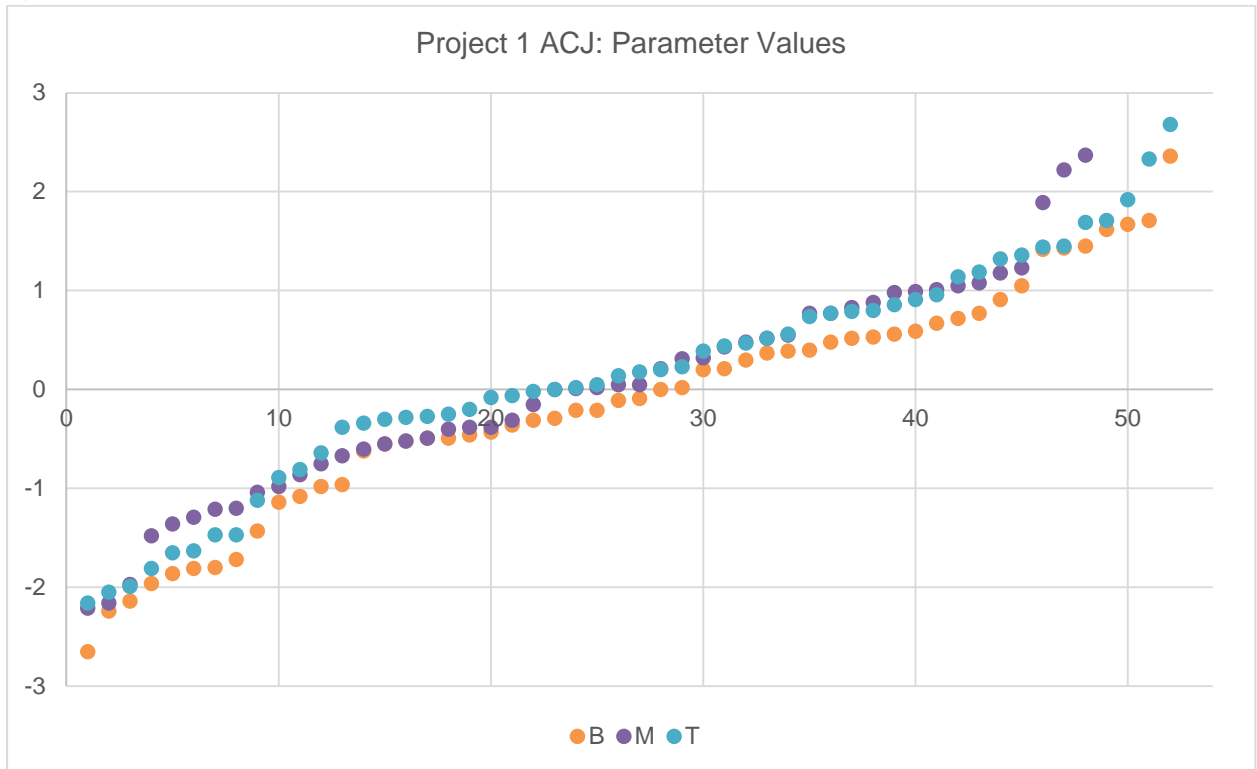
Table 3

Results from Likert-Scale Questions

#	Group B			Group M			Group T		
	Mean	SD	Count	Mean	SD	Count	Mean	SD	Count
1	5.11	1.05	36	5.23	1.29	31	5.39	1.32	33
2	3.36	1.34	36	3.06	1.50	31	3.15	1.64	33
3	5.50	1.30	36	5.68	1.09	31	5.76	0.99	33
9	5.17	1.21	36	5.48	1.16	31	5.45	0.99	33
13	4.67	1.18	36	4.61	1.26	31	5.12	1.12	33

Effect sizes were calculated to further analyze the difference among groups. An effect size of 0.21 was found for the results of Likert-scale question #2 between Group B and Group M, suggesting that students who did ACJ at the beginning found the comparison process slightly more challenging than those did ACJ in the middle. An effect size of 0.26 (Group B vs Group M) and 0.25 (Group B vs Group T) was found for question #9 which suggests that the students who reviewed projects through ACJ at their revising stage learned slightly more from being a judge than the ones who did ACJ at their brainstorming stage only. Finally, the survey results suggested that students who used ACJ more frequently indicated they learned more through making comparative judgments with an effect size of 0.39 between Group B and T and 0.43 between Group M and T.

a)



b)

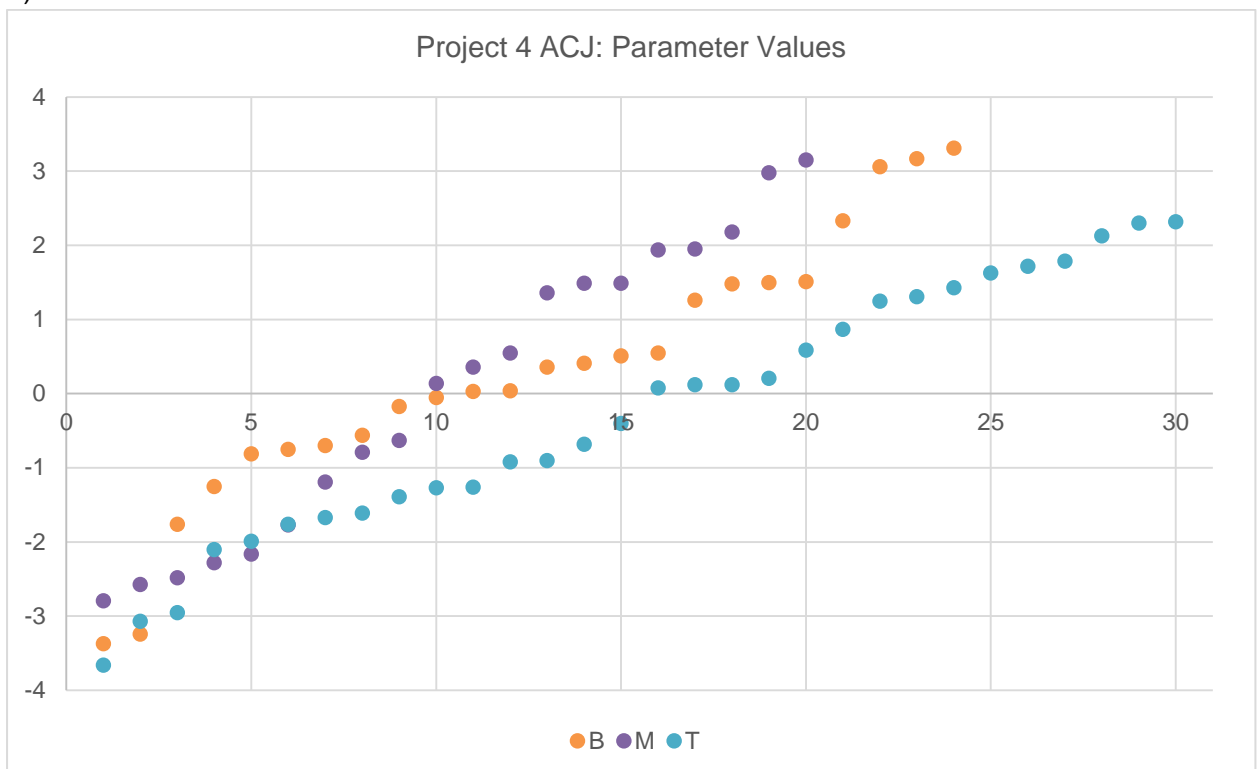


Figure 11. Parameter values generated with ACJ shown in scatter charts

RQ2: What are student perceptions of using ACJ as a formative assessment and learning tool?

In addition to the quantitative analysis of responses student quotes, collected through the surveys, were also analyzed and compared in an effort to triangulate and further explore the findings. A few representative excerpts, obtained from the survey responses, are included here to illustrate student feelings related to using ACJ at different points in their learning process:

By making comparative judgments, I found out some of my work's weakness. For example, I realized that I did not have enough emphasis in my work.

I learned that some color schemes and design schemes really do not fit well together.

I learned how to pick out one or two specific things from a piece that make it have greater visual attractiveness than the other piece.

I learned about thinking more about how to be more specific so the person understand what they specifically need to change.

Student comments touched on a variety of ideas related to ACJ for learning. For example, students highlighted specific strengths and weaknesses—of their work and that done by others— which could be worked on, graphic design principles and their application in the project, strategies for approaching the design task more effectively, and how their work might be viewed/perceived by others. A detailed analysis of comments, which is ongoing, may yield further insight into the experiences of students while engaged in ACJ.

Discussion & Conclusion

The findings of this study were limited in two ways, 1) the three student groups were taught by different instructors, which could be a factor influencing their performance; 2) not every student submitted their projects at the time of reviewing due to the course schedule. Further study is already underway as the researchers are conducting a longitudinal study applying a similar methodology with classes taught by one instructor. Findings from this study suggest that ACJ, whenever it is utilized in the design learning process, appears to be a benefit to student learning. It may be that the timing is not as important as the inclusion of an ACJ experience.

Specifically, this research showed that the use of ACJ at different positions in a design did not significantly affect student achievement. This was illuminating as previous research suggested that implementing ACJ in peer formative assessment can improve student learning (Bartholomew, et al., 2019). Despite no significant different in achievement, students who had the ACJ peer assessment experience with ACJ at different points during design process did hold slightly different perceptions towards ACJ.

We suggest further investigation into the potential for using ACJ as a learning tool. Specific research into the best way to incorporate ACJ into learning scenarios would add insight for teachers looking to improve student learning. Further, an analysis of the student's comments—provided to their peers through ACJ—may yield additional insight into their experiences, learning, and how ACJ influences the overall process

Reference

- Barrett, T. (2000). Studio critiques of student art: As they are, as they could be with mentoring. *Theory into Practice*, 39(1), 29-35.
- Bartholomew, S. R. (2017). Assessing Open-Ended Design Problems. *Technology and Engineering Teacher*, 76(6), 13-17.
- Bartholomew, S.R., Strimel, G.J., & Yoshikawa, E. (2018). Using Adaptive Comparative Judgment for Student Formative Feedback and Learning During a Middle School Open-ended Design Challenge. *International Journal of Technology & Design Education*, 1-23.
- Bartholomew, S. R., & Yoshikawa, E. (2018). A systematic review of research around Adaptive Comparative Judgment (ACJ) in K-16 education. *Council on Technology and Engineering Teacher Education: Research Monograph Series*.
- Bartholomew, S. R., Zhang, L., Strimel, G. J., & Garcia Bravo, E. (2019). A Tool for Formative Assessment and Learning in a Graphics Design Course: Adaptive Comparative Judgement. *The Design Journal*, 1-23.
- Canty, D., Seery, N., Hartell, E., & Doyle, A. (2017). Integrating Peer Assessment in Technology Education through Adaptive Comparative Judgment. *PATT34 Technology & Engineering Education—Fostering the Creativity of Youth Around The Globe, Millersville University, Pennsylvania, USA*, 10-14.
- DigitalAssess (2018). *What we do: CompareAssess*. Retrieved on November 20, 2018 from <http://digitalassess.com/what-we-do/#compareassess>
- Ehmann, D. (2005, November). Using assessment to engage graphic design students in their learning experience. In *Making a Difference: 2005 Evaluations and Assessment Conference Refereed Papers*.
- Findeli, A. (2001). Rethinking design education for the 21st century: Theoretical, methodological, and ethical discussion. *Design issues*, 17(1), 5-17.
- Heldsinger, S., & Humphry, S. (2010). Using the method of pairwise comparison to obtain reliable teacher assessments. *The Australian Educational Researcher*, 37(2), 1-19.
- Hokanson, B. (2012). The design critique as a model for distributed learning. In *The next generation of distance education* (pp. 71-83). Springer, Boston, MA.
- Jones, I., & Alcock, L. (2013). Peer assessment without assessment criteria. *Studies in Higher Education*, 39(10), 1774-1787.
- Kimbell, R. (2012). Evolving project e-scape for national assessment. *International Journal of Technology & Design Education*, 22, 135-155.
- Markham, T. (2011). Project based learning a bridge just far enough. *Teacher Librarian*, 39(2), 38.
- Moore, P., & Fitz, C. (1993). Using Gestalt theory to teach document design and graphics. *Technical Communication Quarterly*, 2(4), 389-410.
- Neumann Jr, R. K. (1988). A Preliminary Inquiry into the Art of Critique. *Hastings Lj*, 40, 725.
- Öztürk, M. N., & Türkkan, E. E. (2006). The Design Studio as Teaching/Learning Medium—A Process-Based Approach. *International Journal of Art & Design Education*, 25(1), 96-104.
- Panadero, E., & Jonsson, A. (2013). The use of scoring rubrics for formative assessment purposes revisited: A review. *Educational Research Review*, 9, 129-144.
- Pollitt, A. (2004, June). Let's stop marking exams. In *IAEA Conference, Philadelphia*.
- Pollitt, A. (2012). The method of adaptive comparative judgement. *Assessment in Education: principles, policy & practice*, 19(3), 281-300.
- Seery, N., Buckley, J., Doyle, A., & Canty, D. (2016). The validity and reliability of Adaptive Comparative Judgements in the assessment of graphical capability. In *Proceedings of the 71st Mid Year Conference of the Engineering Design Graphics Division* (pp. 104-109).
- Seery, N., & Canty, D. (2017). Assessment and learning: The proximal and distal effects of comparative judgment. *Handbook of technology education*, 1-14.

Thurstone, L. L. (1927). A law of comparative judgment. *Psychological Review*, 34(4), 273–286.

Walker, M. (2015). The quality of written peer feedback on undergraduates' draft answers to an assignment, and the use made of the feedback. *Assessment & Evaluation in Higher Education*, 40(2), 232-247.

Appendix. Full List of Survey Questions

Part I. Likert-Scale Questions (1-strongly disagree, 7-strongly agree)

Statement 1	Overall, I enjoyed the ACJ comparison process.
Statement 2	I feel the ACJ comparison process was difficult.
Statement 3	I think it was helpful to act as judge and make comparative judgments between peer work.
Statement 4	I made changes to my own design based on what I saw as I did the peer critique.
Statement 5	I looked at the feedback I received after each peer review session.
Statement 6	I made changes based on the feedback I provided to others.
Statement 7	I made changes based on the feedback I received from others.
Statement 8	I think the feedback was helpful in improving my own design.
Statement 9	I feel I learned as I acted as a judge.
Statement 10	Providing feedback to my peers helped me to better identify and understand the design project criteria.
Statement 11	My learning was most strongly impacted by providing feedback.
Statement 12	My learning was most strongly impacted by receiving feedback
Statement 13	My learning was most strongly impacted by making the judgments between items.

Part II. Open-ended Questions

1. Please provide a short paragraph reflecting on the experience of using *CompareAsses*.
2. Thinking about when you compared items, when you choose one item over another, what influenced your decision?
3. Please provide any specific examples of what you learned from
 - a. Making comparative judgments?
 - b. The feedback you received?
 - c. The feedback you provided?

Another way of teaching programming.

Lars Björklund



Lars Björklund
Linköping University
Sweden
lars.bjorklund@liu.se

ABSTRACT

Programming has become a mandatory school subject in many countries. In Sweden computer science and programming was introduced in the national curriculum in 2018 as part of mathematics and technology. In years 7–9 pupils are supposed to learn about technical solutions that use electronics and how they can be programmed. A focus is on understanding systems for control and automation, with the aid of programming. (Education, 2018).

Technology teachers do not, as a rule, have any computer science or programming in their own training and all over Sweden in-service training have started to help them in their new teaching task. Preliminary outcomes are discouraging; many teachers drop out, failing in these traditionally taught university computer science courses.

By using results from research on difficulties in programming and coding, part of a university programming course for teachers was redesigned and tested. The teachers solved technological problems incorporating sensors and actuators where a program was one, but just one, part of the system. They learned concepts like variables, conditionals and loops by reading input from sensors and taking different actions according to the values detected. Different kinds of actuators, motors, relays, LEDs were controlled resulting in simplified control- and alarm-systems. Graphical programming with the Microbit computer was used. Even though the programs produced were very small, most of basic coding concepts were addressed.

The course ended in a larger project where the teachers applied their knowledge in their own classroom. They documented the project and a self reflection on their own learning process. These documents are used in this paper to discuss the challenges teachers will meet in their new task.

Keywords: In-Service Courses, Block-based Programming, Teaching/Learning strategies, Novice Programmers, Learning Programming

The In-service course, basic programming for teachers

Technology teachers working in year 7 to 9 were invited to an in-service course in programming. The course was part of a national program with similar courses for teachers in technology but some courses were for teachers in mathematics. 16 teachers showed up for the first meeting on campus and 14 have completed the course so far. One or two were already proficient in programming and just needed some university credits, but the majority were novices with little or no experience of programming or of teaching programming. They worked at home on different assigned tasks and met with university teachers during three full separate days. A web portal was used to communicate with each other and the staff. For assessment, two reports were written by every participant. One describing a programming project they had designed and realized with their pupils and another paper with personal reflections on the different parts of the course, problems, insights etc. This conference paper reports their experiences, coupled with studies on programming to describe a way to teach programming to nonprogrammers.

The complexity of programming

The complexity of learning to program has been studied by many researchers and was addressed by Robins (2010) when he proposed the model of "Learning edge momentum". He suggested that difficulty in learning a programming language is related to its domain of tightly integrated concepts, where almost every concept depends on many others. If the learner fails early in a course this will make later learning even harder and this could explain the large number of drop-outs found in programming courses. Many programming concepts have been found challenging: variables (Du Boulay, 1986), loops, conditionals and procedures (Soloway, 1986) are difficult and often pupils only use sequences in their programs (Aivaloglou & Hermans, 2016). By using physical programming i.e. reading signals from sensors, processing that data, and using it to control actuators many of these programming concepts seem to be easier to learn. Gender differences will also decrease (Rubio, Romero-Zaliz, Mañoso, & de Madrid, 2015)

In the year before the introduction of programming in the curriculum, conferences on digital competence, computational thinking and programming were offered to teachers all over Sweden. The complexity of teaching programming was deemphasized and the teachers were told they could learn together with the pupils. The idea of computational thinking was promoted and was probably one strong argument for the reintroduction of programming as a compulsory subject in school. There are many definitions of computational thinking but the general idea was that by solving problems with a computer, skills would be trained that could transfer into other areas. The notion of computational thinking "datalogiskt tänkande" was eventually left out of the new curriculum but it still lives in people's minds.

The process of designing a course for these teachers was started with a comprehensive review of the literature. To find good literature about pedagogy and "didactics" in programming education you have to look back in history. During the late 1970s and 1980s computer science and programming was hot in many school systems and several of the most seminal papers were written in those days and have been lost in darkness since. The problems with programming and the basic concepts have not changed and several important topics needed to be addressed in the design of the course, including:

- The notional machine
- Gender issues
- Problems in programming languages

Notional machine

The student has to understand the notional machine (Sorva, 2013), the artifact he or she is going to program. What can it do and how should it be programmed. It is often confusing for

a student to differentiate between the computer used for writing the program (the development machine) and the computer that will execute the code (the target machine). What pops up on the screen could be from either. It therefore seems to be useful to work with a single board computer (SBC) detached from the development computer. The program is written and compiled on the development system and then downloaded to the SBC which could be moved and, stand alone, do some control task.

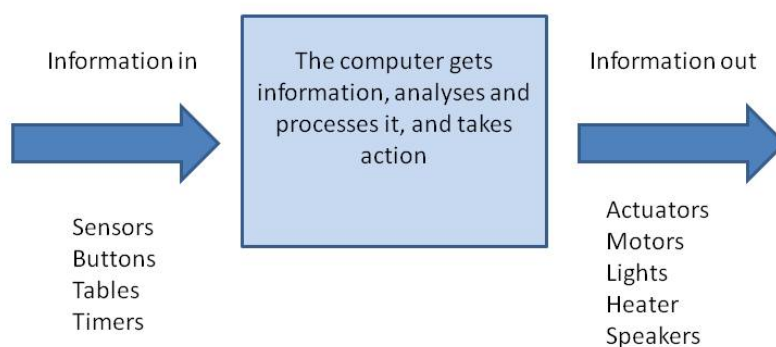
There are many examples of SBC's on the market. The BBC Microbit, invented for educational purposes was chosen for this study as it has been proven as a useful educational computer in both the UK and Denmark. The Microbit has internal sensors, display, buttons and could be expanded with a lot of different interfaces to use other sensors and control motors of different kinds.

The choice of language was a bit complicated should we go for a block-based or a text-based language? The literature is a bit divided about this. Many authors liked the idea of using a text-based language like C++, Java or Python but research studies seemed to favor the block-based approach. Weintrop and Wilensky (2017) found that students working with blocks were learning faster and they developed a more positive attitude towards learning more about computer science than a control group working with a text-based language. A block based language makes it easier to handle the syntactical rules of a language and the scope of instructions like IF THEN ELSE, WHILE, REPEAT is much easier to understand with a graphical framework. We decided to try the Microbit block-based language for the first part of the course. A useful feature of the block editor is that one can easily switch to and fro between the block-editor and a text-based Javascript editor.. In the second part of the course we used a Raspberry Pi SBC and a text-based language, Python. The teachers designed and tested lessons in programming for their own pupils using hardware and software of their own choice. All of our teachers used the Microbit in their projects, and they all agreed that the block-based language was the correct choice for their 14 to 16 year old pupils. They considered Python to be a better language for use in math education but not for technology tasks.

Educational structure of the in-service course

The curriculum states that the teacher should facilitate that “Pupils’ own constructions in which they apply control and regulations, including with the aid of programming” is addressed. Does this mean that the pupil should learn how to program, to become a programmer? No it doesn't. The time to learn a programming language isn't there; the subject of technology has a lot of other tasks to fulfill and goals to meet. Building constructions where a computer is one component in a system with sensors and actuators would be enough. An important part of technology education is systems. It is important that you can use a model of an information processing system where the computer is one of the components and where sensors and actuators are as important as the program.

Information processing system



Many problems in real life can be avoided with this type of systems thinking and the specific examples the pupils are studying are just examples of something more general knowledge on control systems. A sensor for light could be exchanged with a sensor for temperature and the lamp replaced by a heating element but the program would be similar.

A plan was designed where different technological problems were addressed, for example detecting a digital signal from a switch; measuring an analogue voltage from different sensors; measuring time between two events. To make the examples more relevant they also included the control of the temperature of a mug of water and similar control systems. There were examples on the use of different actuators, relays, and different electrical motors. Every example in the practical laboratory session was a small system with a sensor as input, a small program and some kind of output. The examples were chosen so that the most important instructions in the languages; variables, conditionals, loops and different kind of I/O, were used in a typical context. The teachers who were novices were a bit confused in the beginning but got some confidence when the small projects eventually worked out, and they understood that they were fulfilling some of the requirement of the curriculum.

Gender issues

When a subject in school becomes mandatory one has to look into the attitudes towards the subject from different groups of pupils. Computer science has for many years been a “boys project” and the number of girls interested in computing is very small. Something happened in 1984 when the number of women in computer science courses plummeted (McGrath Cohoon, 2001). Even today in most countries the percentage of women in this field is very low. Several studies have been made trying to understand and maybe changing this fact, hopefully getting women interested again (Seneviratne, 2017; Singh, Allen, Scheckler, & Darlington, 2007; Sparkes, 1992).

Some studies have shown that women lose interest when the relevance and the use of the computer is postponed to a later time in the course (Margolis & Fisher, 2000). A course focusing only on a specific programming language and its syntax is not so good in that respect. Cultural aspects do have their relevance and it is interesting to see how in Malaysia and the Philippines among others the girls are in a majority of computer science students. Girls seem to appreciate to work in pairs, they want to be able to ask questions to the teachers and if they see relevance they perform as well as and often better than boys. Physical computing, doing something in the physical world, seems to promote the interest of girls (Hussain, Lindh, & Shukur, 2006). Projects on the human body, measuring pulse, breathing and other examples from medical technology seem to be interesting for both sexes (Jidesjö & Oscarsson, 2004). The use of a SBC like Microbit and its sensors also seem to have some effect on girls' attitudes. Rocks (2017) found that 39% of girls said they would definitely do ICT/Computer Science as a subject option in the future, up from 23% before they used the Microbit.

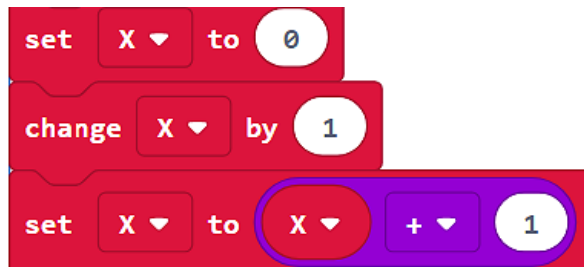
The teachers in our course had to read a literature review on gender and programming and had a seminar where this and another paper were discussed. Several of the teachers had not heard of this “problem” before and some were worried how they should get the teenage girls to engage in programming.

Problems in programming

Variables

One of the problems our teachers found, working with their projects, was that their pupils did not understand the concept of variables. This is a problem also described in the literature. In the subject of mathematics variables are used for something unknown and most often used in algebraic equations like $X=21-2X$ and eventually evaluated to $X=7$. In programming the use

of a variable could be a named location in memory where we may store values: $X=1$ which means put the numerical value in the memory location labeled X. The other use is to get the value that is stored in the memory location X as in $X=X+1$ which means take the value of X and add the number one and put the result in memory position X. These different use of a variable will make things hard for a student. There is also some shorthand versions used for incrementing a variable that could be hard to understand. The construct of variables in block based program seemed to make things easier, according to some teachers.



$X = 0$
 $X += 1$
 $X = X + 1$

We tried to use one of the ideas from literature, where values read from an external sensor should be stored in a variable. Since the values could not be anticipated during coding it would be relevant and natural to store it somewhere. The block based program uses the “Set variable to xx” which make what is happening very clear. The javascript version is not as obvious:



`GetTemperature = pins.analogReadPin(AnalogPin.P0)`

Conditionals

Pupils are using conditionals but there are some caveats. The teachers saw that the WHILE loop was sometimes misinterpreted especially when the pupils were coding in Python. The IF THEN ELSE seems also to be hard to understand even though the graphical frame is a good help in its use. Sometimes pupils believe that they only have to write one IF instruction in the program and that the computer will keep on testing it even when it is executing other parts of the program. In the same way pupils are using the IF as in ordinary conversation. You only have to say IF once. This is part of what Pea (1986) calls the “Superbug”, that the novice thinks that the computer will know what you meant it to do and that it will execute all instructions all the time.

Repetition

In some languages there is a “forever loop”. This is a very common way of coding a program and it will lead to an infinite loop where the program never stops until the device is switched off. We found that some of our teachers were coding several forever loops in the same program, just because they found several interesting examples in the same page of a book.

Debugging

The lack of good debugging tools was a problem but not as big as anticipated. The programs developed by the teachers and their pupils were very short and the use of functions and the block editors simulator helped to some extent.

What kind of projects did the teachers develop for their classes

Not surprisingly the teachers found that the differences in competence among the pupils were enormous, maybe more than in any other subject. Some very interested and proficient, pupils

quickly completed their tasks and wanted more challenges. Other pupils struggled even with the easiest tasks and basic programming concepts. Many ambitious plans and time schedules didn't work out in reality.

The most successful projects started very basic with unplugged computing exercises and proceeded at a slow pace with many repetitions and concrete demonstrations. Two teachers working with a group of 16-year old pupils that had failed most subjects in school happened to find a topic that made these boys engage in schoolwork. A parent called and asked what had happened to his son who returned home from school unusually happy. He had been the guru of the technology class helping his classmates and answering to their questions, and found something that he was good at. These pupils were building a machine for counting hammer strokes, not a very complicated program but it worked and they had ideas of how to measure speed and force in the stroke. Another teacher combined some teaching about electronic components and how they could be used as inputs and outputs of the Microbit, and how the system could be documented.

Conclusions

Most of the projects became rather small in volume which made us, as course designers; realize that we shouldn't set goals which are too ambitious for this part of the technology curriculum. This also means that it is very important how we chose the examples and the tasks in our teacher training courses. The idea of teaching teachers to learn how to teach programming in a short university course seem a bit unrealistic even if we succeeded to help most of our teachers to find a way forward.

The idea of presenting small examples of computerized control systems and their associated programs, instead of teaching a full programming language seem to be a profitable way of addressing these teachers' request for help. Building a toolbox of useful solutions to common problems is a way to initiate the bank of programming schemata of a programming expert.

References

- Aivaloglou, E., & Hermans, F. (2016). *How Kids Code and How We Know: An Exploratory Study on the Scratch Repository*. Paper presented at the ICER '16, Melbourne.
- Du Boulay, B. (1986). Some Difficulties of Learning to Program. *Journal of Educational Computing Research*, 2(1), 75-93.
- Education, S. N. A. f. (2018). *Curriculum for the compulsory school, preschool class and school-age educare 2011: Revised 2018*. Norstedts Juridik kundservice.
- Hussain, S., Lindh, J., & Shukur, G. (2006). The effect of LEGO Training on Pupils' School Performance in Mathematics, Problem Solving Ability and Attitude: Swedish Data. *Swedish Data. Educational Technology & Society*, 9(3), 182-194.
- Jidesjö, A., & Oscarsson, M. (2004). *Students' attitudes to science and technology: First results from The ROSE-project in Sweden*. Paper presented at the XI IOSTE, Lublin, Poland.
- Margolis, J., & Fisher, A. (2000). Women in computer science: Closing the gender gap in higher education. *Final Report to the Sloan Foundation*.
- McGrath Cohoon, J. (2001). Toward Improving Female Retention in the Computer Science Major. *Communications of the ACM*, 44(5), 108-114.
- Pea, R. D. (1986). Language-Independent Conceptual "Bugs" in Novice Programming. *Journal of Educational Computing Research*, 2(1), 25-36.
- Robins, A. (2010). Learning edge momentum: A new account of outcomes in CS1. *Computer Science Education*, 20(1), 37-71.

- Rocks, S. (2017). BBC micro:bit celebrates huge impact in first year, with 90% of students saying it helped show that anyone can code Retrieved 11/24, 2018, from <https://www.bbc.co.uk/mediacentre/latestnews/2017/microbit-first-year>
- Rubio, M. A., Romero-Zaliz, R., Mañoso, C., & de Madrid, A. P. (2015). Closing the gender gap in an introductory programming course. *Computers & Education, 82*, 409-420.
- Seneviratne, O. (2017). Making Computer Science Attractive to High School Girls with Computational Thinking Approaches: A Case Study. In P. J. Rich & C. B. Hodges (Eds.), *Emerging Research, Practice, and Policy on Computational Thinking* (pp. 21-32). Cham: Springer.
- Singh, K., Allen, K. R., Scheckler, R., & Darlington, L. (2007). Women in Computer-Related Majors: A Critical Synthesis of research and Theory From 1994 to 2005. *Review of Educational Research, 77*(4), 500-533. doi: 10.3102/0034654307309919
- Soloway, E. (1986). Learning to program = learning to construct mechanisms and explanations. *Communications of the ACM, 29*(9), 850-858.
- Sorva, J. (2013). Notional Machines and Introductory Programming Education. *ACM Transactions on Computing Education, 13*(2).
- Sparkes, R. A. (1992). *Teaching control technology to girls*. Paper presented at the IDATER, Loughborough.
- Weintrop, D., & Wilensky, U. (2017). Comparing Block-Based and Text-Based Programming in High School Computer Science Classrooms. *ACM Transactions on Computer Education, 18*(1), 25. doi: <https://doi.org/10.1145/3089799>

Learning through design and make: Producing originally-thought-out products versus producing pre- designed products downloaded from data files.

Vomaranda Joy Botleng, Stéphane Brunel, Philippe Girard



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



Stéphane Brunel
Université de Bordeaux
France
stephane.brunel@u-bordeaux.fr



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

ABSTRACT

According to neuroscience studies, whenever something is learned, the neural networks in the brain are created, altered or strengthened. Piaget elaborated on this learning as the alteration of mental models. Literature has shown that iterative activities cause neurons to fire more frequently making the experiences more intense thus increases the likelihood for the event to be encoded as a memory in the Long Term Memory. In Digital Fabrication Laboratories (fablabs) equipped with the latest low-cost production machines, computer-aided design (CAD) programs and computer-aided manufacturing (CAM) programs, iterations between the stages of a design process can take place. Several authors have claimed that iterations between the stages of design process help students develop a better understanding of the materials, tools, requirements or specifications, develop a more complex understanding of relevant engineering concepts and will be more likely to arrive at a more favourable product. This paper presents findings from two studies into production in a university-based fablab (Ub-Fablab). Production Study one (PS1) focused on a group of students producing an originally-thought-out product while Production Study two (PS2) focused on a production of a pre-designed product downloaded from data files. The study used the Nawita Design Process Model (NDPM) to track the design activities. Results showed that producing an originally-thought-out product made from many raw materials and using different types of production machines and tools in PS1 allowed more iterations between the design stages compared to the production of a pre-designed product downloaded from data files using only one raw material and one production machine in PS2. This study will provide some guidelines for educators on how to choose student projects that will best harness learning through design and make.

Key Words: Learning, Bloom's Taxonomy, Nawita Design Process Model, Originally-thought-out products, pre-designed products, Iterative design process model

1 INTRODUCTION

Modern day studies in neuroscience have very much been influenced by Hebb's postulate which talked about how the repeatedly and persistent firing of the axons of one neuron cell with another influences growth metabolism of both cells thus increasing their efficiencies (Mastin, 2010; Baddeley 1986; Baddeley 2000)). Neurons are brain cells that transmit electrochemical signals (nerve signals) to and from the brain and the nervous system at up to 200mph. These neurons 'communicate' with each other through the synapses (see Figure 3). Whenever something is learnt, neural networks are created, altered or strengthened (Mastin, 2010).

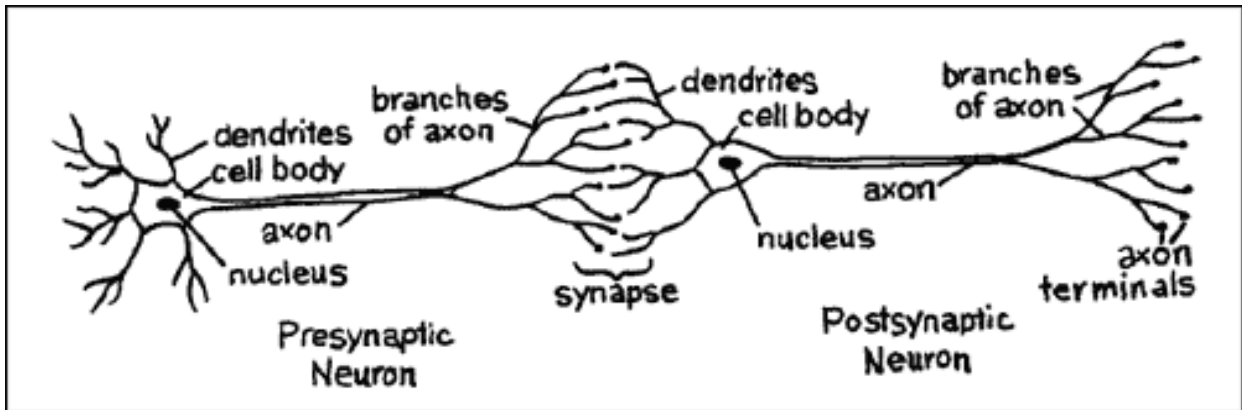


Fig 3 Presynaptic and postsynaptic neuron in position for transmission

[Source:<https://science.education.nih.gov/supplements/nih2/addiction/guide/lesson2-1.html>]

Literature in neuroscience has shown that iterative activities cause the neurons to fire more frequently making the experiences more intense thus increases the likelihood for the event to be encoded as a memory in the Long Term Memory (LTM) (Mastin, 2010; Baddeley 1986; Baddeley 2000). An iterative activity is defined as '*...the process of doing something again and again, usually to improve it*' (Merriam-Webster, n.d., p.1). The iterative activities in a University based digital fabrication laboratory (Ub-Fablab) refer to the design processes that take place.

Ub-Fablabs provide cutting-edge production machinery such as the 3D printers, laser-powered cutters and etchers, table-top milling equipment, high-precision robotic routers to enable students to design and produce. Standardized IBM-compatible computers supported by Computer-Aided Engineering (CAE) software such as i) Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software programs allow iterations between each stage of the design process. There are also traditional production tools in the Ub-Fablab where this study took place.

This study builds from a previous study presented in Patt-34 conference. Production Study one (PS1) focused on a group of students producing an originally-thought-out product (see Botleng, Brunel and Girard, 2017) while Production Study two (PS2) (this study) focused on a production of a product downloaded from Thingiverse. PS1 product (Figure 1) is made from many types of raw materials, uses both traditional and modern production machines including a 3D printer and produced in a group while PS2 product (Figure 2) is made from a single raw material, used a single modern production machine, the 3D printer and is produced by one person.



Figure 1 PS1: Production of an originally-thought-out product



Figure 2: PS2: Product downloaded from the Internet

The key question that guided this study is:

What are the influences of the following aspects of design and production on (a) the number of iterations and (b) the degree to which cognitive processes are unleashed?

- a. The type of product to be designed
- b. composition of product (many types of raw materials versus only 1 raw material)
- c. types of production machines used (a variety of traditional and modern production tools and machines versus using only modern production tools and machines)
- d. a group of people producing a product together versus one person producing a product

Exploring some answers to this key question will provide some understanding for educators on how to choose projects that will best enhance learning.

2 THEREOTIC BACKGROUND

1. Piagetian Theory of Learning

Students learn when they construct knowledge. Learning is simply the process of adjusting our mental processes to accommodate new experiences and this is done through a process called adaptation which is the ability to adjust one's environment (Piaget 1952). The four main concepts postulated by Jean Piaget that drive this construction of knowledge are Assimilation, Accommodation, Equilibration and Schemas. Assimilation and accommodation are both part of the adaptation process. Piaget believed that human beings possess mental structures that assimilate external events and convert them to fit their mental structures. These mental structures accommodate themselves to new, unusual and constantly changing aspects of the external environment. In order to organize and accommodate this assimilated information from the environment, a state of equilibrium between the external world and the internal mental structures, called the Schema or Schemes has to be achieved. To achieve this, students have to interpret, make alterations or change their belief systems (Bhattacharya & Han, 2001, p.1).

The **encoding process** is enhanced by the cognitive processes in the brain (Piaget 1952). According to Piaget (1952) the incoming stimuli is **adapted** by the cognitive process of **assimilation, accommodation** and **equilibrium** in line with the 'schema' or '**schemata**' (plural of schema). A schema as 'a cohesive, repeatable action sequence possessing component actions that are tightly interconnected and governed by a core meaning'. Piaget called these schemas the basic building blocks of intelligent behaviour-a way of organizing knowledge. It can be thought of as 'units' of knowledge, each relating to one aspect of the

world, including objects, actions and abstracts concepts (McLeod 2009, p. 3). Piaget believed that the cognitive development did not take place at a steady rate, but rather in leaps and bounds driven by the equilibration force (see Figure 4).

Whenever there is an incoming stimulus, assimilation takes place using existing schema to deal with the new object or situation. Equilibrium can take place only if the child's schema can deal with the incoming stimuli or new object or situation. If the incoming stimuli does not suit the existing schema, adjustments have to be made to deal with the new object or situation, thus be accommodated. Once the new information is acquired the process of assimilation with the new schema will continue until the next time we need to make adjustments to it (McLeod 2009, p. 5).

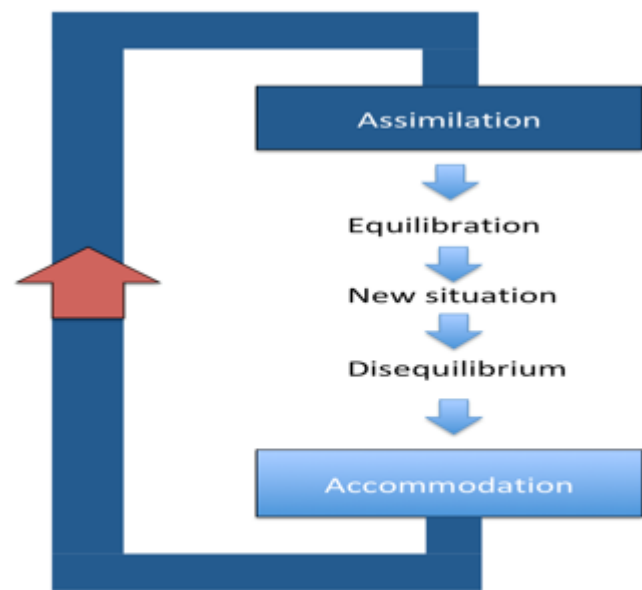


Figure 4 Assimilation, Accommodation and Equilibrium Process

The activities in places like the Ub-Fablab are ones that involve constant retrieval of information, reconstructing, consolidating and storing of information in the LTM. The repeated actions and processes like those found during iterations found in iterative design processes cause physical changes in the structure of neurons. Synapses become more or less important over time (plasticity) and is based on experience and only on local information (Hebb's postulate) (Bear et al, 2001). The physical changes within the body of neurons involve the creation of new proteins. The creation of new protein in the neutrons strengthens the electrochemical transfer of neurotransmitters across synapse gaps to receptors and also reinforces the communication strengths of certain circuits of neutrons in the brain. With repeated use, the efficiency of these synapse connections increases, facilitating the passage of nerve impulses along particular neural circuits, which may involve many connections to Pre-frontal Cortex (PFC) (Mastin, 2010). The PFC of primates, believed to be the most developed part of a mammalian brain (Barbas, 1988; Jones & Powel, 1970; Kawamura & Naito, 1984; Nauta, 1972; Panda, Dye, & Butters, 1971; Panda & Selzer, 1982 cited in Nishijo, Ono & Yamatani 1990, p. 503) is highly activated during activities, in particular the cerebellum, putamen, caudate nucleus and the motor cortex where procedural information encoded and stored in LTM is retrieved. According to a study done in 1986 on non-human primates (Nishijo, Ono, Nakamura, Kawabata, & Yamatani, 1986; Nishijo, Ono, Namakura, Tamura & Muramoto, 1987; Kubota & Funahashi, 1982; Kubota & Komatsu, 1985 cited in Nishijo, Ono & Yamatani, 1990, p. 528), the ventral putamen showed neuron responses to task-dependant activities and the number of PFL neuron responses increased as the learning of tasks progresses Various other lesion studies suggest PFC neurons involvement in volition or attention, reward-related functions, orientation, and movement initiation or suppression (see reviews by Rosenkilde, 1983 cited Nishijo, Ono & Yamatani, 1990).

2. Cognitive processes in design and Bloom's Taxonomy

An early research on design by Hall (Hall, 1962 cited in Eastman, 1968) identified the sequence of activities in a design as '*problem identification, data gathering, analysis, synthesis, and evaluation*'. Other authors further divided the initial design activities into, '*determination of a need, identification of the relevant parameters and criteria, generation of*

initial concepts for plausible solutions, and preliminary evaluation of them in terms of physical realizability and financial feasibility (Eastman 1968, p. 1). Eastman (1968) referred to design as an 'intuitive process' since, '*little is known about the sequence of activities that produce a creative design and since its procedures are implicit and self-taught*' (p.1). He went to argue that

Lacking for design education is knowledge about how basic design concepts are normally generated and how different activities are integrated to produce an original product. Before significant improvements in the intellectual powers of designers and in design methods are possible, its first seems necessary to determine what comprises self-taught and intuitive design processes (ibid, p.2).

Being intuitive alone is a challenge for anyone doing research into these processes. This research therefore uses a classification of learning behaviours that is widely known as the Bloom's Taxonomy to align with the observable learning behaviour (OLB) that take place during design in a fablab. The taxonomy has arisen from Bloom's initial research into OLB under the three domains of learning: Cognitive, Psychomotor and Affective in 1956 (Bloom, 1956). This research uses the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001). Other terms that are used by other authors are Knowledge (for cognitive), Skills (for psychomotor) and Attitudes (for Affective). In this study, the OLB associated with the cognitive, psychomotor and affective will be closely observed, recorded and analysed to give answers to the questions that guide this study.

3 METHODOLOGY

3.1 Participants

Extreme purposive sampling (Flick, 2009) is used in this study. According to Davis (2007) the core sample is the people that make up the 'pivotal target group' and are therefore able to provide the essential insights necessary to answer a projects research question. In this study, the PS1 participants are a group of 5 elementary teacher trainees working on a Rock Milling Machine project (RMM, for short). The RMM project involved a range of wood, stone and synthetic material technologies, skills and knowledge. PS2 participants, on the other hand, is one person, using a 3D printer to produce a pre-designed product (a chain) downloaded from data files.

3.2 Data collecting method and analysis

Because it is not possible to directly observe what a person is thinking, this research used a method that is used by theorists in the fields of behavioural analysis to study thinking. This method is an adapted protocol analysis method (see Crutcher 1994; Simon and Kaplan 1989; Austin and Delaney 1998 cited in Ericsson, 1993). An iterative design process model called the 'Nawita Design Process Model' (NDPM) (refer to Botleng, Brunel & Girard, 2016; Botleng, Brunel & Girard, 2017 for details of NDPM), derived from the Iterative Development Model (Martinez & Stager 2013) was used to trace the activities. The researcher, a non-participant observer in this study, captured the activities using field notes, video recording and still photography. The recorded data is then analyzed to find out the

- i) number of iterations between each stage of NDPM.
- ii) the cognitive processes that are unleashed in each stage.

For ii) Observable learning behaviors (OLB) are teased out and aligned with Bloom's Taxonomy of cognitive, psychomotor and affective domains of learning (refer to Bloom, 1956; Anderson & Krathwohl, 2001 for details of Revised Bloom's Taxonomy). The percentage occurrences of the cognitive, psychomotor and affective skills are calculated and displayed in Table 1 and Table 2 in the result section and graphed using a bubble graph. The researcher chose to use a bubble graph over the others as a bubble graph allows one to see three variables on the graph unlike the other graphs where only two variables can be shown. In this

research, the bubble size gives the magnitude of the cognitive, psychomotor and affective skills at each stage of NDPM.

4 RESULTS

1. PS1 Iterations

The group iterated between the four stages of NDPM taking routes 1-9 to finally come up with their product (Figure 5).

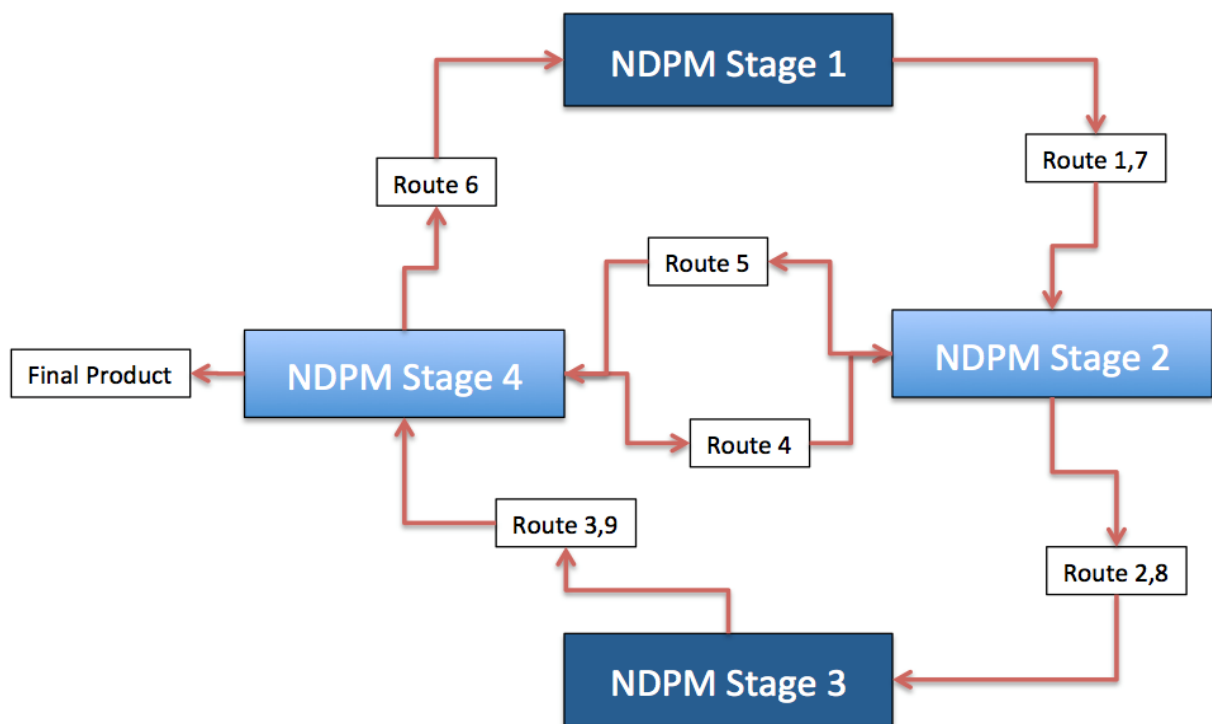


Figure 5 The Iteration Pathway in PS1

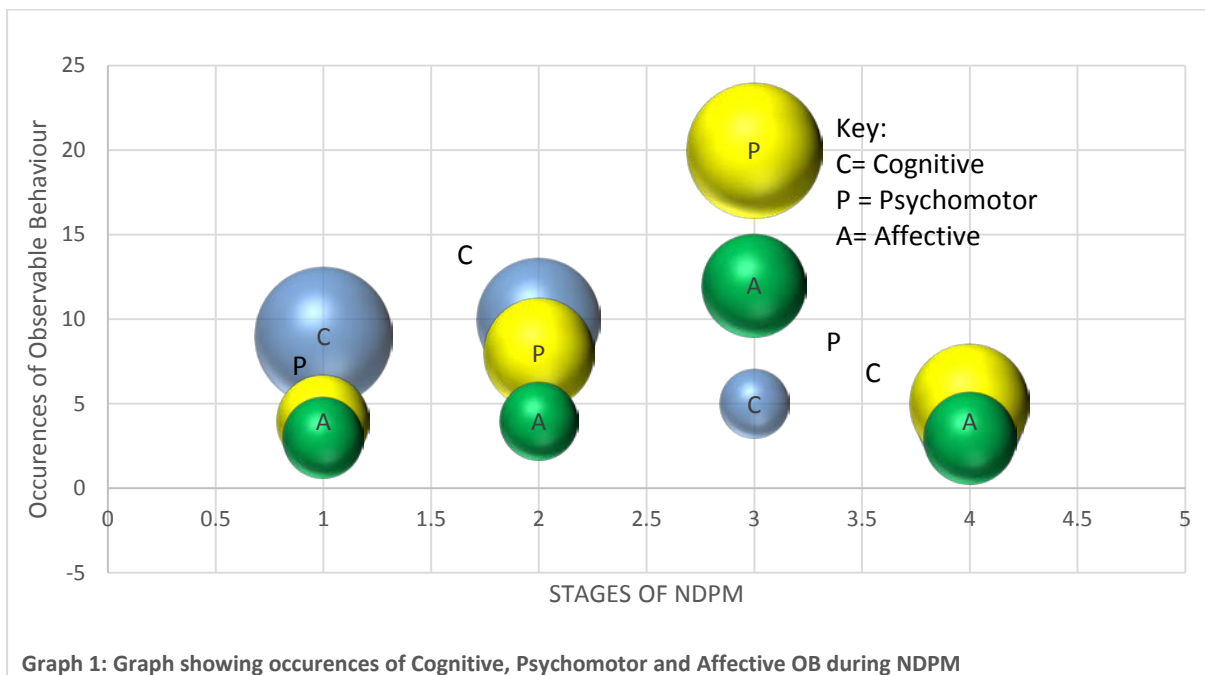
A summary of the occurrences of observable behaviour and the magnitude of each skill at each stage are outlined in Table 1 and depicted in graph 1 below.

Table 1 : Occurrences of OLB in stages 1-4 of NDPM of PS1

NDPM Stage	Cognitive Skills (%)	Psychomotor Skills (inclusive of M2E)	Affective Skills (%)
1	55	9	36
2	30	35	35
3	18	47	35
4	46	15	39

Source: Botleng, Brunel and Girard, 2017

The frequency at which each of the cognitive, psychomotor and affective observable behaviour at each stage is graphed using bubble-graphing (Graph 1).



Source: Botleng, Brunel and Girard, 2017

PS2 Iterations

The person producing the downloaded product took only two routes (routes 1 & 2) to produce the chain.

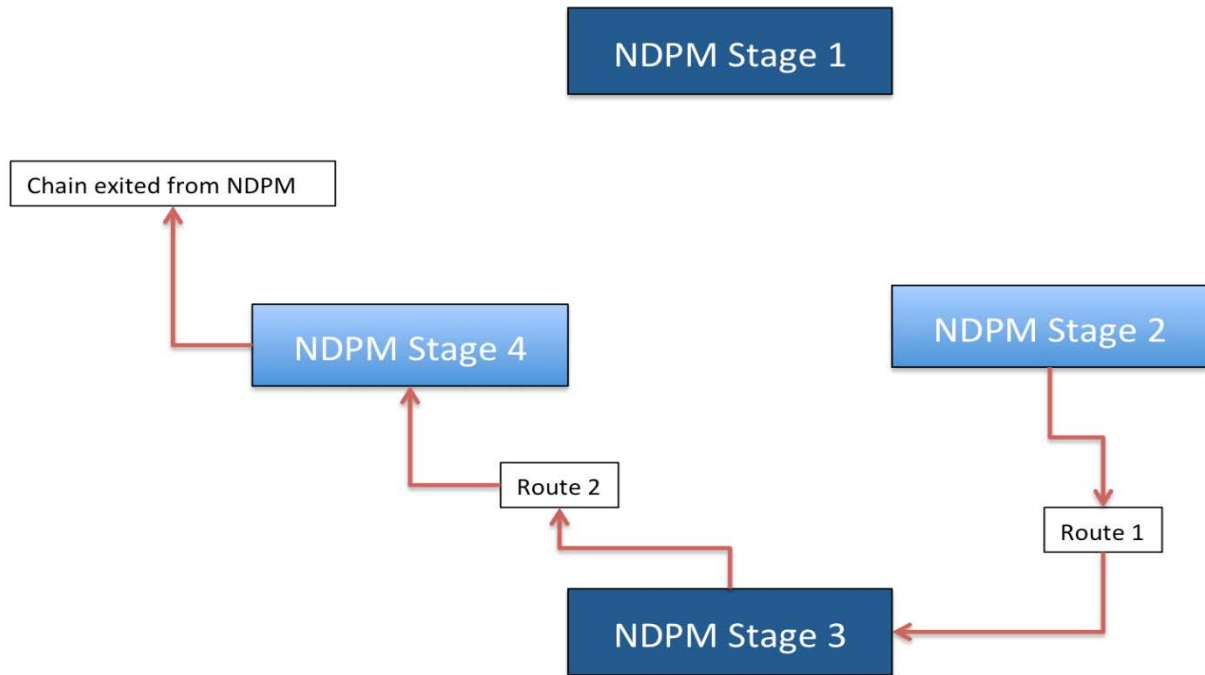


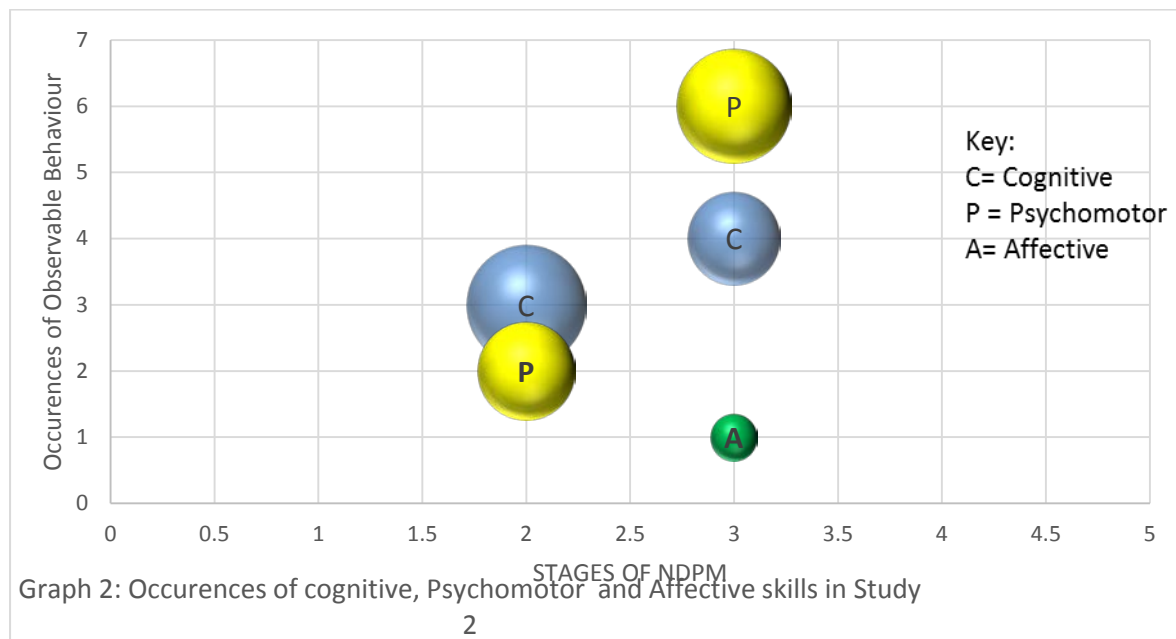
Figure 5.8 Iteration Pathways in PS2

A summary of the occurrences of observable behaviour and the magnitude of each skill at each stage is outlined in Table 2 and depicted in graph 2 below.

Table 2 : Occurrences of OLB in stages 1-4 of NDPM in PS2

NDPM Stage	Cognitive Skills (%)	Psychomotor Skills (inclusive of M2E)	Affective Skills (%)
1	0	0	0
2	60	40	0
3	40	60	10
4	0	0	0

The occurrences of OLB is shown in graph 2 below.



2 DISCUSSION

1. Producing an original thought-out product versus producing a product downloaded from data files

Graph 1 shows a high peak of cognitive, psychomotor and affective skills in stages 1 compared to 0% of OLB in graph 2. The RMM produced in PS1, being an originally-thought-out product, a lot of cognitive processes are used to start conceiving a mental representation of the product. The retrieval of declarative knowledge from LTM to the WM and PFC cognitive skills including creative thinking, critical thinking and decision making are dominant in stage 1. In PS2, the chain being pre-designed product downloaded from a data file, a designer has done the conceiving process.

PS1 product being an originally thought-out product students iterated through the NDPM stages twice. Arriving at stage 4 (Evaluation and Testing) one part of the RMM did not function as expected so the group iterated back to stage 1 to rethink, discuss, visualise and create new solutions. The part that did not function was made of stone therefore the group decided to replace it with a 3D printed part. This iterations have produced stunning peaks of cognitive processes as shown in graph 1. The product in PS2, on the hand, exited the NDPM without further alterations thus showed 0% in stage 4 in graph 2.

2. Producing a product composed of many raw materials versus producing a product composed of only 1 raw material

PS1 product is made of many different types of raw materials: rock, wood and PLA filament. A lot of cognitive OLB is expected as a lot of decisions have to be made on the best material to use and their physical and chemical properties of these raw materials that would make them the best materials to use. Mathematical knowledge and skills are also applied to work out the product specifications. The iterations in PS1 have allowed the revisit of neural circuits in mathematical calculations.

PS2 product, on the other hand, is made of only 1 raw material, the PLA filament. The only cognitive process involved here is declaration knowledge of the types of PLA filaments and the choice of colour. The OLB presented in graph 2 therefore showed very little occurrence of cognitive and psychomotor skills in stage 2.

3. Producing a product using many types of different production machines versus producing a product using just one type of production machine

In stage 3 of NDPM (the production stage), PS1, the group of students used a wider range of traditional and modern production machines and tools to produce the RMM. For example a hand saw was used to cut the rock into a circle while an electric drill was used to bore holes in the rock and wood. Measuring tapes were used to measure the circumference of the rock. Calibrations were also done on the 3D printer to print a part for the RMM. This involved a lot of cognitive processes involving the prefrontal cortex (PFC) of the brain and the cerebellum. This is reflected in the high peaks of cognitive, psychomotor and affective OLB in stage 3 of graph 1.

In PS2, on the other hand, the only production used was a 3D printer. The only knowledge required in stage 3 is the knowledge required to set the working temperature of the 3D printer, the speed at which to set the 3D printer and setting the Layer height (the person gets a choice as to set it up at either 0.4mm, 0.3mm or 0.1mm).

4. Producing a product in groups versus one person producing a product

PS1 product was produced by a group of students compared to PS1 Product produced by one person alone, there is a huge difference in the occurrences of the affective OLB in PS1 compared to the affective OLB observed in PS2 in graphs 1 and 2 respectively. The students working together as a group exhibited a higher percentage of affective OLB in all stages of NDPM compared to a tiny fraction of affective OLB in PS2.

6. CONCLUSION AND RECOMMENDATIONS FOR FURTHER RESREACH

Overall this study has highlighted the following aspects of design and production that has contributed to multiple iterations and unleashed the highest peaks of Blooms' cognitive, psychomotor and affective skills:

- 1 producing an originally-thought-out product
- 2 producing a product composed of many raw materials
- 3 producing a product using many types of production machines
- 4 producing a product in groups

There are, however, some limitation to this study worth mentioning. This study being carried out into a little-researched field, the research tools used to trace the activities, collect and analyse data are either developed (e.g. the NDPM) or adapted from various sources in related fields. The study therefore may be served as an exploratory research study to lay some groundwork for future research into the alignment of cognitive processes with design. The tools used in this study could make a good starting point in developing research instruments for future research in this field.

REFERENCES

- Anderson, L., & Krathwohl, D.A. (2001). *Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York, NY: Longman.
- Asimow M. (1962). *Introduction to Design*. UK, Prentice Hall.
- Baddeley, A.D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, 4, (11), 417-423.
- Baddeley, A.D. (1986). *Working Memory*. Oxford, England: Oxford University Press.
- Bear, M.F.; Connors, B.W. & Paradiso, M.A (2001). *Neuroscience: Exploring the Brain*. Baltimore: Lippincott. ISBN 0-7817-3944-6.
- Bhattacharya, K, & Han, S. (2001). Piaget and cognitive development. In M. Orey (Ed), *Emerging perspectives on learning, teaching and technology*. Retrieved (4 June 2015), from 'http://epltt.coe.uga.edu
- Blessing, L.T.M. (1994). *A process-based approach to computer supported engineering design: context, theory and practice*. UK, Prentice Hall.
- Bloom, B.S. (Ed.). Engelhart, M.D., Furst, E.J., Hill, W.H., & Krathwohl, D.R. (1956). *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain*. New York, NY: David McKay Co Inc.
- Boettcher, J.V (2008). *Designing for Learning*. CERN. Retrieved from <http://www.designingforlearning.info/jvb/index.html>
- Botleng, V.J., Brunel, S., & Girard, P. (2016). The Digital Fabrication Laboratories (Fablabs) Platform: A dynamic Hands-on, Minds-on and Hearts-on Approach to augment STEM Education activities and 21st Century Skills. Conference proceedings from *PATT-32 Conference on Technology Education for 21st Century Skills, Utrecht, Netherlands, 20-26 August 2016*, 10-117. Retrieved from <https://www.iteea.org/File.aspx?id=39504&v=>
- Botleng, V.J., Brunel, S., & Girard, P. (2017). Unleashing cognitive processes via materialization of creative thinking using fablab technological infrastructures. Conference proceedings from *PATT-34 Conference on Technology Education for 21st Century Skills, Philadelphia, USA, 20-26 July 2017, 10-14*. Retrieved from <https://www.iteea.org/File.aspx?id=39504&v=>
- Davis, M.B. (2007). *Doing a successful research project*. New York : Palgrave MacMillan.
- Eastman, C. M. (1968) *Explorations of the Cognitive processes in design*. Pennsylvania, PA: Carnegie Mellon University Research. Retrieved from <http://www.repository.cmu.edu/compsci>
- Engelbrecht, W. (2016). Learning and teacher support material to promote 21st Century skills for junior secondary school students. Conference proceedings from *PATT-32 Conference on Technology Education for 21st Century Skills proceedings, Utrecht, Netherlands, 20-26 August 2016*, 158-169. Retrieved from <https://www.iteea.org/File.aspx?id=39504&v=>

- Ericsson, K.A, Simon, H.A (1993). *Protocol Analysis: Verbal Reports as Data*. Cambridge MA: MIT Press.
- Flick, U. (2009). *An introduction to qualitative research*. 4th edition. London : Sage.
- Hemorrhage [Def. 1]. (n.d.). *Merriam-Webster Online*. In Merriam-Webster. Retrieved January 2, 2013, from <http://www.merriam-webster.com/dictionary/citation>.
- Martinez, L.M., & Stager, G. (2013). *Invent to Learn*, Torrance CA: Constructing Modern Knowledge Press.
- Mastin, L. (2010). *Types of memory- The Human Memory*. Retrieved from <http://www.human-memory.net/types.html>
- McLeod, S. (2012). *Simply Psychology: Working memory*. Retrieved from <http://www.simplypsychology.org/working%20memory.html>
- Mercola: Neuroplasticity studies reveal your brain's amazing malleability. Retrieved July 15, 2015 from <http://articles.mercola.com/sites/articles/archive/2015/01/15/neuroplasticity-brain-health.aspx>
- Merriam-Webster Online*. In Merriam-Webster. Retrieved May 25, 2018, from <http://www.merriam-webster.com/dictionary/citation>.
- Nishijo, T., Ono, T & Yamatani, K.(1990). Activity and Distribution of learning related neurons in monkeys (*Macaca fuscata*) prefrontal cortex. *Behavioural Neuroscience*, 104 (4), 503-531. <http://dx.doi.org/10.1037/0735.104.4.503>
- Simpson E.J. (1972). *The Classification of Educational Objectives in the Psychomotor Domain*. Washington, DC: Gryphon House.
- The Theories of Jean Piaget*. "TeAchnology. (2011, February 13). Teachnology, Inc. Retrieved April, 14 from <http://www.teachnology.com/currenttrends/constructivism/piaget/theories.html>

Teaching modelling using digital tools in secondary technology education: Teachers' experiences.

Helen Brink, Nina Kilbrink, Niklas Gericke



Helen Brink
Karlstad University
Sweden
Helen.brink@kau.se



Nina Kilbrink
Karlstad University
Sweden
Nina.kilbrink@kau.se



Niklas Gericke
Karlstad University
Sweden
Niklas,gericke@kau.se

ABSTRACT

Models can be used for communicating and for sharing information. In technology education in Swedish compulsory school, pupils have long created models using simple materials to test their designs, such as cardboard and wooden sticks. Models have also been used by teachers to assess pupils' technology knowledge in particular areas (Elmer & Davies, 2000). We live in a world where technology is highly developed, where digital technology plays an important role and where models are created in digital environments (Kress, 2010). Technology as a school subject undergoes the same development, which can be seen in the technology syllabus (Skolverket, 2011). However, there is a lack of research on technology teachers' experiences of teaching modelling using digital tools. According to previous research, teachers' experiences of a phenomenon (Marton & Tsui, 2004) along with their pedagogical and technological knowledge (Mishra & Koehler, 2006) affect how they plan their lessons. The aim of this pilot study is therefore to examine secondary school teachers' experiences of teaching modelling using digital tools, thereby contributing to understanding this area of technology education. The study takes a phenomenographic approach (Marton & Booth, 1997) and is based on semi-structured interviews with teachers. The interviews are analyzed, focusing on how technology teachers experience teaching modelling using digital tools. Their different experiences are divided into categories. So far, four categories have been identified: a) Modelling using digital tools as inspiration, b) Handling the modelling software as the object of learning, c) Handling 3D printing as the object of learning and d) Modelling for teaching technological content. A tentative result is that teachers have different aims and purposes when teaching modelling using digital tools.

Keywords: Model, modelling, digital tools, technology education, secondary school, phenomenography, computer-aided design.

Introduction

Models and modelling play an important role in secondary schools' technology curriculum (Skolverket, 2018). Visual support is needed when pupils (and professionals) develop a product. Often, describing a product by only using words is not enough; there is a need for sketches, drawings and models. Models in technology education are representations that are used to explain objects, technical solutions or phenomena (Norström, 2013). They carry information about something because it is a representation (Gilbert, Boulter & Elmer, 2000). The models can for instance be scale models of details or technical systems or they can be used to concretize technical processes. Pupils can study parts, mechanisms and systems with the help of the models. Modelling, on the other hand, is a part of the manufacturing process during which pupils can test their ideas, and the function and design of the product under construction. Pupils also have the opportunity to learn about working with different materials and using different manufacturing techniques when modelling. Models and modelling are also a way of presenting ideas to yourself, as well as communicating with other pupils, teachers and intended customers. In school, the modelling process is also important because it allows teachers to assess pupils' knowledge and grasp of the object of learning (Elmer & Davies, 2000).

Today, more information is communicated through digital media, and different kinds of models are created and visualized in digital environments. This change requires citizens to be digitally competent, since they need to interpret and create models on their own using digital tools. There are different types of digital competences, such as interacting and sharing through digital technologies, developing, integrating and re-elaborating digital content as well as solving technical problems and creatively using digital technologies. These competences are connected to three of the areas in the European Commission's framework for digital competence for citizens (Carretero, Vourikari & Punie, 2017), namely Communication and collaboration, Digital content creation and Problem solving. One of the Swedish school's tasks is to develop digital competence among pupils (Skolverket, 2011), and using digital tools for modelling, as described above, can be a way of achieving that competence. One example of a digital modelling tool is computer-aided design (CAD), which is commonly used in Swedish secondary schools today.

What do technology teachers want their pupils to learn when modelling using digital tools? A lesson design, or the design of a series of lessons, depends on many factors. The teachers' knowledge and experiences of the phenomena and the object of learning is one such factor, but there are other important factors too, such as pedagogical knowledge, curriculum knowledge and knowledge about the group of pupils (Shulman, 1986). Teachers' experiences of the object of learning, in this study modelling using digital tools, have an effect on what teachers prepare for the pupils to learn, or the intended object of learning (Marton & Tsui, 2004; Mishra & Koehler, 2006). Preparation involves transforming the subject matter, into ways of teaching, or different ways of representing the content or making it accessible to pupils. The teacher therefor must analyze *what* to learn and *how* it should be learned (Mishra & Koehler, 2006). Bjurulf (2011) also highlights the importance of the technology teacher's awareness of *what* to teach and *why* it should be taught. Otherwise, there is a risk that the pupils do not reflect on their learning, or that learning does not occur, if pupils do not understand the relevance of the intended object of learning (Bjurulf, 2011).

Teachers' experiences form the basis of the intended object of learning. The intended object of learning is enacted as the object of learning in the classroom context, and that affects the lived object of learning and what the pupils actually learn (Marton & Tsui, 2004). This pilot study is limited to teachers' experiences of teaching modelling using digital tools and phenomenography is used as a methodological framework. The different experiences are categorized qualitatively. Teachers were interviewed, asked to describe their teaching of modelling using digital tools.

Aim

The aim of this paper is to present the findings on six secondary technology teachers' experiences of teaching modelling using digital tools. There is a need for research that explains teachers' experiences of modelling using digital tools to enhance the understanding of the intended object of learning – *what* is to be learned and *how* it can be learned – in order to develop technology education in this area.

Theoretical background

Modelling using digital tools and documentation in the form of digital models in technology education are a part of the manufacturing process (Skolverket, 2018). It gives pupils opportunities to functionally test their design (France, 2018). Digital tools are used in technology education, and one of them are computer-aided design (CAD). Ginestié (2018) writes that it is important to develop a technological interest among pupils, an understanding of how digital tools are used in a contemporary society and how digital tools can be used to solve different problems, and using CAD can be helpful.

To be able to design and model using CAD, pupils need both procedural and strategic knowledge. Procedural knowledge concerns handling the software, the commands and menus. Strategic knowledge concerns how to build your design, in what ways you can make solids and surfaces and how easy it is to change and choose between different modelling strategies (Chester, 2007). Previous research shows that pupils modelling using CAD do not develop their creativity and problem solving skills (Leisney & Brandt-Pomares 2015). Research also shows that teachers helping pupils with procedural guidance reduces the pupils own cognitive thoughts (Ginestié, 2018). The procedural help is not useful for the pupils when developing meaning and understanding of a content. However, we know very little about teachers' experiences about teaching digital modelling in technology education where this study can contribute with more knowledge.

This study takes a phenomenographic approach. In the phenomenographic tradition developed by Marton (1981) and colleagues, the manner in which different people experience the same phenomena in qualitatively different ways is described. These differences depend on which aspects of the phenomena are prominent in the person's awareness and which aspects remain marginal. What a person discerns also depends on their previous knowledge and experiences.

In the phenomenographic tradition, experiences are described from a second order perspective, because the researcher interprets the utterances from the interviewees. The second order perspective means therefore that these are not descriptions of the phenomenon itself, but descriptions of different experiences of the phenomenon (Marton, 1981; Trigwell, 2006). In this study, qualitatively different categories of experiencing teaching modelling using digital tools are identified in the analysis. Different people are aware of different aspects of the same phenomena and therefore the phenomena appear in different shapes. If a person for instance discerns two aspects simultaneously, the phenomenon is experienced in a certain way, while the experience of another person who discerns three aspects differs (Marton & Booth, 1997). There is usually a limited number of categories for experiencing the same phenomenon (Rovio-Johansson & Ingerman, 2016). It is not interesting from whom the utterances come (Marton & Booth, 1997; Booth & Ingerman, 2002), the categories and relations between the categories are of interest.

Method

In this study, semi-structured interviews were used to collect data, because this gives interviewees the opportunity to answer the questions in depth, and to discuss different dimensions of variation in the phenomenon that they find necessary for explaining their experiences. An interview guide and prepared questions were used to frame the phenomenon

and to make sure that different perspectives were fully covered. An interview guide could also be a tool for ensuring that the interviewees reflect upon the same phenomenon. This is important: if the experiences do not concern the same phenomenon, the results cannot be deemed phenomenographic (Rovio-Johansson & Ingerman, 2016).

Technology teachers are not a homogeneous group. In Sweden, about half of the teachers have not been specifically trained to teach technology as a secondary school subject (Skolverket, 2019). According to a report from the Swedish Schools Inspectorate (Skolinspektionen, 2014), technology education takes many different forms in different schools, and this likely also applies to the area of modelling using digital tools. Therefore, it is important to capture different experiences of teaching modelling using digital tools to enhance discussions on technology education and to develop technology teachers' profession. The participants were chosen strategically to cover a wide spectrum concerning gender, education and the length of their experience of teaching technology (Alexandersson, 1994). If the data were collected from a group of similar teachers, there would be a risk of not covering all the aspects of the phenomenon researched (Alexandersson, 1994). The participants were contacted via e-mail and gave their informed consent to participate on the basis of the information they received about the project, the digital recordings and their voluntary participation. The number of participants and interviews were not determined beforehand; data collection must continue until saturation is reached.

The interviews were recorded digitally and transcribed by one of the researchers with a focus on the content of the interviewees' utterances, rather than the manner in which such content is expressed. Transcription constitutes a transformation from spoken to written language and this transformation is an important passage (Kvale, 1996); the aim of the transcriptions must therefore guide the transformation. For the sake of readability and in line with the aim of this study, the transcriptions resemble written rather than spoken language.

Up to the present, six interviews have been conducted in the pilot study and five of them have been transcribed. One of the interviews could not be used, due to technical problems. The interviews were held at the teachers' schools in a location decided by the teachers, so that they would feel as comfortable as possible.

The analysis process started in parallel with the interviews, because tentative categories can usually already be identified during the interviews (Marton & Booth, 1997). The data material was listened to and read several times to find overall meaning and to identify units of descriptions. Thereafter the differences between the units were identified and described and the logical relations between the units were clarified. Finally, the units of description were categorized. Thereafter the transcriptions once again were read to ensure that all the different experiences fit into a category and that no experience has been omitted. This cycle of work will continue and more interviews will be conducted until saturation is reached.

Results

While reading the transcriptions, units were identified from the data and they have so far been described and divided into categories. The categories are different experiences of teaching modelling using digital tools. Four categories with distinct differences have been identified:

- a) **Modelling using digital tools as inspiration.**
- b) **Handling the modelling software as the object of learning.**
- c) **Handling 3D printing as the object of learning.**
- d) **Modelling for teaching technological content.**

The different ways of experiencing modelling using digital tools is the result of different aspects in the teachers' awareness (Marton & Booth, 1997). Descriptions of each category and the example excerpts of how teachers express their experiences are presented below. The excerpts are out of context, but have been chosen to support and give substance to the categories. The results indicate, as is discussed further in the next section, that there are different experiences of teaching modelling using digital tools.

a) **Modelling using digital tools as inspiration.**

Description: Teachers experience the phenomenon as a way of learning about different engineering professions, seeing technological tools used outside school, and inspiring the pupils to pursue higher education in technology.

Teacher 5: ...my role is to show *what* there is, then my second role is to show *how*, and my last role is to build up an interest [...] General knowledge is never wrong, you know. Maybe, you [the pupil] will find this so amazing that you will do it professionally later.

Teacher 3: I want them [the pupils] to get some base knowledge about its existence.

b) **Handling the modelling software as the object of learning.**

Description: Teachers base the modelling object on the pupils' interests more than on a technical artefact or technical solution, as long as they learn to handle the software, both strategically and procedurally. Models already made using CAD software and displayed in libraries and databases are used to inspire the pupils when deciding what to design and model. The technological learning that occurs is random and depends on the different problems the pupils encounter (for instance, scale and angles). Different pupils face different learning situations.

Teacher 1: But math and scale and so, you take that step by step. If you notice someone doing grids [software settings] that are five times five centimeters instead of 30 millimeters, then maybe you must...

Teacher 3: ... it is the same with the tasks in 3D I have given them. I haven't limited them at all. Some of the pupils have done a name tag. The simplest thing. And some have done things that [...] so big. So I try not to limit the tasks, I like to have opportunities for the pupils to fly away.

Teacher 3: Above all, it is their, I mean how they go further [...] how they maneuver the software and that they can manage it on their own. The task hasn't been more controlled than that.

c) **Handling 3D printing as the object of learning.**

Description: What the pupils design and model is of minor importance, as long as the model can be printed using a 3D printer. The teachers experience 3D printing as a new way and modern way of manufacturing details in plastics, and want the pupils to learn how to do it.

Teacher 2: [...] and then digital tools are great, and you can design. I think 3D printers are terrific. I think that is the future, instead of ordering a part, you can print the knob to the washing machine that is loose. Print it and it is done.

Teacher 3: Now I should do something in Tinkercad [a software for modelling] that can be printed.

Teacher 3: I have explained [to the pupils] that it [the printer] cannot start printing in the air. If so, the threads will be hanging.

d) **Modelling for teaching technological content.**

Description: The technological content is general and can for instance involve developing an understanding of the three-dimensional coordinate system or of scale.

Teacher 5: Well, then it is X, Y and Z that must have correct values. And they [the pupils] must understand that there are other values to fit in to.

Discussion

This study is still inconclusive, and the categories are preliminary. Despite this, it is important to note that for some teachers, it is the modelling tool which seems to be the object of learning when modelling using digital tools. What the pupils are modelling is not the focus of the teachers' lesson design. That is distinguished from modelling with simple construction materials, where the design and construction itself are the object of learning and pupils are supposed to learn specific technological content (Norström, 2013). When modelling using digital tools, the technological content itself does not seem important, instead, *how* the pupils manage to design using the digital environment of the software is more important. When designing and modelling using simple materials, the important aspects are the technological content, not how the pupils use scissors and glue to cut and mount. Implementation of new technologies gives the older techniques a new meaning (Alexandersson, 2014; Mishra & Koehler, 2006). Modelling with simple construction materials may therefore be given new meaning as modelling using digital tools becomes more common in classrooms.

However, one category comprises technological content, but very generally, such as scale and three-dimensional coordinate systems. Further interviews need to be conducted to find out if this category can contain other technological content too, as is the case when modelling with simple construction material, such as mechanics, transmission or design.

It is also important to note that teachers must know *how* a 3D printer prints to teach the pupils this manufacturing method. The teachers (and the pupils) must understand the importance of support, and why surfaces cannot start from nothing. Otherwise, the result will be thin plastic filaments hanging free.

A category can hierarchically be included in a more complex category (Trigwell, 2006). The results from this study imply that category **b) *Handling the modelling software as the object of learning***, can be included in both categories **c)** and **d)**. To be able to print a digitally designed object, the pupils must handle the software. Likewise, to be able to learn technological content, such as the three-dimensional coordinate system, the pupils must also be able to handle the software.

Conclusion

The results discussed in this paper indicate that teachers teach modelling using digital tools with different aims and purposes; the intended objects of learning differ, and pupils therefore have different prerequisites for education in this area. To answer the question *How do technology teachers in secondary school experience teaching modelling using digital tools?*, it is important to continue this study to clarify the categories further and to understand the differences and relations between the categories.

References

- Alexandersson, M. (1994). Den fenomenografiska forskningsansatsens fokus. In Starrin, B., & Svensson, P. G. (1994). *Kvalitativ metod och vetenskapsteori*. Lund : Studentlitteratur.
- Bjurulf, V. (2011). *Teknikdidaktik*. Stockholm : Norstedts.
- Booth, S., & Ingerman, Å. (2002). Making sense of physics in the first year of study. *Learning and Instruction, 12*, 493-507.
- Carretero, S., Vourikari, R. & Punie, Y. (2017). *The digital competence framework for citizens: With eight proficiency levels and examples of use*. Luxembourg: Publications Office of the European Union.
- Chester, I. (2007). Teaching for CAD expertise. *International journal of technology and design education, 17*(1), 23-35.
- Elmer, E., & Davies, T. (2000). Modelling and creativity in design and technology education. In Gilbert, J. K., & Boulter, C. J. (2000). *Developing models in science education* (ss. 137-156). Dordrecht : Kluwer Academic, cop. 2000.
- Erixon, P-O. (red.) (2014). *Skolämnen i digital förändring. En medieekologisk undersökning*. Lund: Studentlitteratur.
- France, B. (2018). Modeling in technology education: A route to technological literacy. In M. J. de Vries (Red.), *Handbook of Technology Education* (ss. 611-621). Cham: Springer International Publishing. doi:10.1007/978-3-319-38889-2_45-1
- Ginestié, J. (2018). Using computer technologies in design and technology education: Teaching-Learning process. In M. J. de Vries (Red.), *Handbook of Technology Education* (ss. 403-418). Cham: Springer International Publishing.
- Gilbert, J. K., Boulter, C. J., & Elmer, R. (2000). Positioning models in science education and in design and technology education. In J. K. Gilbert & C. J. Boulter (Red.), *Developing models in science education* (ss. 3-17). Dordrecht: Springer Netherlands.
- Kress, G. R. (2010). *Multimodality : a social semiotic approach to contemporary communication*. London : Routledge, 2010.
- Kvale, S. (1996). *Interviews : an introduction to qualitative research interviewing*. Thousand Oaks, California : Sage, 1996.
- Laisney, P., & Brandt-Pomares, P. (2015). Role of graphics in the learning design process. *International journal of technology and design education, 25*(1), 109-119.
- Marton, F. (1981). Phenomenography - Describing conceptions of the world around us. *Instructional science, 10*, 177-200.
- Marton, F. (2015). *Necessary conditions of learning*. New York : Routhledge.
- Marton, F., & Booth, S. (1997). *Learning and Awareness*. Mahwah, N.J : Erlbaum.
- Marton, F., & Tsui, A. (2004). *Classroom discourse and the space of learning*. Mahwah, N.J : Erlbaum.
- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.
- Norström, P. (2013). Engineers' non-scientific models in technology education. *International Journal of Technology & Design Education, 23*(2), 377-390. doi:10.1007/s10798-011-9184-2
- Rovio-Johansson, A. & Ingerman, Å. (2016). Continuity and development in the Phenomenography and Variation theory tradition. *Scandinavian Journal of Educational Research, 60*(3), 257- 271, DOI: 10.1080/00313831.2016.1148074
- Schulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.
- Skolinspektionen. (2014). *Teknik – gör det osynliga synligt. Om kvaliteten i grundskolans teknikundervisning*. Stockholm. Retrieved from <http://www.skolinspektionen.se/Documents/Kvalitetsgranskning/teknik/kvalgr-teknik-slutrapport.pdf>

- Skolverket. (2011). *Läroplan för grundskolan, förskoleklassen och fritidshemmet 2011*. (Reviderad 2017) <https://www.skolverket.se/publikationer?id=3813>
- Skolverket. (2018). *Kursplan teknik*. Hämtad från <https://www.skolverket.se/undervisning/grundskolan/laroplan-och-kursplaner-for-grundskolan/laroplan-lgr11-for-grundskolan-samt-for-forskoleklassen-och-fritidshemmet?url=1530314731%2Fcompulsorycw%2Fjsp%2Fsubject.htm%3FsubjectCode%3DGRGRTEK01%26tos%3Dgr%26p%3Dp&sv.url=12.5dfce44715d35a5cdfa219f>
- Skolverket. (2019). *Grundskolan – Personalstatistik med behörighet – per ämne och kategori*. Hämtad från http://siris.skolverket.se/reports/rwservlet?cmdkey=common¬geo=&p_verksamhetsar=2016&p_omgang=1&report=personal_amne2&p_skolkod=&p_lankod=&p_kommunkod=&p_hman=00&p_niva=H&p_amne=18&p_verksform=11
- Trigwell, K. (2006). Phenomenography: An approach to research in geography education. *Journal of Geography in Higher Education*, 30(2), 367-372.

Investigating perceptions of intelligence as an approach to understanding female representation in technology and engineering education.

Jeffrey Buckley, Tomás Hyland, Niall Seery, Lena Gumaelius, Arnold Pears



Jeffrey Buckley
Athlone Institute of Technology, Ireland
KTH Royal Institute of Technology, Sweden
jbuckley@ait.it



Tomás Hyland
University of Limerick, Ireland
tomas.hyland@ul.ie



Niall Seery
Athlone Institute of Technology, Ireland
nseery@ait.it



Lena Gumaelius
KTH Royal Institute of Technology, Sweden
lenaqu@kth.se



Arnold Pears
KTH Royal Institute of Technology, Sweden
pears@kth.se

ABSTRACT

Gender representation in technology and engineering education is generally not equitable with females being underrepresented in many areas (e.g. Sultan, Axell, & Hallström, 2018; Yoder, 2017). While there are many perspectives on gender representation in technical fields, from the perspective of advancing engineering and technology as disciplines, an underrepresentation of females indicates a potential loss of talent. It is therefore pertinent to continue trying to understand why this gender disparity exists.

The field-specific beliefs hypothesis (Leslie, Cimpian, Meyer, & Freeland, 2015) suggests that women are underrepresented to a greater extent in academic disciplines perceived by practitioners to require more raw intellectual talent. In a large scale study, Leslie et al. (2015) provided evidence supporting this hypothesis above three competing hypotheses. Based on these findings, this study explores what 'raw intellectual talent' is perceived to mean in engineering.

In a previous study, Buckley, O'Connor, Seery, Hyland and Canty (2018) found that undergraduate initial technology teacher education students in Ireland perceived intelligence in technology education to describe three components of general, social and technological competence. In this study, the methodology used by Buckley et al. (2018) will be adopted for the context of engineering. A survey asking what characteristics describe intelligence in engineering was administered to university students pursuing bachelor's and master's degrees in a variety of engineering fields in both Ireland and Sweden. The data was coded both inductively and deductively, and frequency statistics were used to analyse the data.

The results suggest that engineering likely has a unique characteristic in terms of engineering competency, and that is it probably knowledge based. In terms of future work regarding gender differences, this suggests that exploring young girls' self-perceptions in terms of engineering specific competencies may be possible, which could significantly impact efforts to address the gender disparity in the field.

Key words: Gender disparity; Field-specific ability beliefs; Implicit theories.

Introduction

In general, technology and engineering educational fields are male dominated (e.g. Sultan, Axell, & Hallström, 2018; Yoder, 2017). This is problematic in terms of the disciplines as a lack of diversity suggests a loss of potential talent. Additionally, from a sociocultural perspective this gender disparity indicates the existence of barriers to women entering these areas. From the perspective of enhancing technology and engineering fields, attracting and promoting diverse talent is a critical agenda to ensure their growth and prosperity. From a sociocultural perspective, it is paramount that all individuals have the opportunity to form and pursue their own aspirations without negative impacts from prejudice or bias. From both positions, there is a clear need to explore the gender imbalance in technology and engineering. A considerable amount of research has been conducted exploring gender diversity in science, technology, engineering, and mathematics (STEM), and in their review of this, Wang and Degol (2017) summarise six explanations for the existence of a gender representation gap including cognitive ability, relative cognitive strengths, occupational interests or preferences, lifestyle values or work-family balance preferences, field-specific ability beliefs, and gender-related stereotypes and biases. This paper describes the initial stages in an exploration into field-specific ability beliefs in engineering education within Ireland and Sweden, which may be able to inform technology education due to the overlap which exists in many contexts.

Much evidence indicates cultural associations between men and innate intelligence but not women (Kirkcaldy, Noack, Furnham, & Siefen, 2007; Tiedemann, 2000) and women tend to be underrepresented in fields which are considered to require innate brilliance in comparison to those where the attainment of excellence or expertise is associated with effort. These stereotypes of women underpinned the postulation of the field-specific ability beliefs hypothesis (Leslie et al., 2015) which suggests that “women may be underrepresented in academic disciplines that are thought to require such inherent aptitude” (Leslie et al., 2015, p. 262). Critically, this is not to suggest that natural ability is or is not important to certain fields in reality, rather this hypothesis is specifically associated with practitioners' opinions concerning the importance of natural ability in the field they are working in. In a large scale study, Leslie et al. (2015) tested this hypothesis against three competing hypotheses; (1) the more demanding a discipline in terms of work hours, the fewer the women, (2) the more selective a discipline, the fewer the women, and (3) the more a discipline prioritizes systemizing over empathizing, the fewer the women. The results of their study supported the field-specific ability hypothesis over the other three, and that the hypothesis extended to the underrepresentation of African Americans' as well.

There are a number of causal explanations associated with this hypothesis. In understanding these, the differences between overt/intentional and covert/subtle forms of sexism, and between hostile and benevolent forms of sexism must be considered (Swim, Aikin, Hall, & Hunter, 1995; Swim, Mallett, Russo-devosa, & Stangor, 2005; Swim & Cohen, 1997). Wang and Degol (2017) note that although overt and deliberate forms of discrimination may not be as common now as they used to be, covert and benevolent forms still exist and shape male and female career trajectories. Notably, research shows that children as young as 6 are influenced by gender stereotypes, such as that science and mathematics as male domains (Miller et al., 2014) and that boys are more likely to be “really, really smart” (Bian, Leslie, & Cimpian, 2017). One example of a causal explanation is related to perceived sense of

community within fields. For example, Cheryan and Plaut (2010) found when studying English, a female-dominated field, and computer science, a male-dominated field, that “the best mediator of women’s lower interest in computer science and men’s lower interest in English was perceived similarity” (p.475). Furthermore, Cheryan and colleagues found that the removal of stereotypical masculine objects (e.g., Star Trek posters and video games) could increase female interest in these courses (Cheryan, Meltzoff, & Kim, 2011; Cheryan, Plaut, Davies, & Steele, 2009). Leslie et al. (2015) summarise additional causal mechanisms for the field-specific ability beliefs hypothesis eloquently, stating that:

The practitioners of disciplines that emphasize raw aptitude may doubt that women possess this sort of aptitude and may therefore exhibit biases against them (Valian, 1998). The emphasis on raw aptitude may activate the negative stereotypes in women’s own minds, making them vulnerable to stereotype threat (Dar-Nimrod & Heine, 2006). If women internalize the stereotypes, they may also decide that these fields are not for them (Wigfield & Eccles, 2000).

The field-specific ability beliefs hypothesis is generally linked with mindsets. Wang and Degol (2017) largely associated it with the work of Dweck and colleagues with reference to fixed and growth mindsets (Blackwell, Trzesniewski, & Dweck, 2007; Yeager & Dweck, 2012). This research reflects the implicit theories which people can have about their own or others abilities, and the capacity for these abilities to change. A similar way of considering peoples implicit theories, the elicitation of prototypical definitions (Neisser, 1979; Rosch, 1977; Rosch & Mervis, 1975; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976), also has significant potential in this agenda. Neisser (1979, p. 182) describes the prototype of a category or concept as being “that instance (if there is one) which displays all the typical properties”. In other words, where providing an explicit verbal definition of a construct is difficult, for example in instances where there is disagreement regarding its remit or structure, generating a prototypical definition allows for a description to be established which puts forward its typical properties as decided upon by a specific cohort of people. So while a prototypical definition may not be an objectively valid definition of a construct, it has substantial importance as it reflects the collective opinion of a specific group of people. The relationship prototypical definitions have with this area of research is that the evidence supporting the field-specific ability hypothesis considers engineering as a singular field relative to 22 other fields and innate ability as a singular construct (Leslie et al., 2015). There is therefore now a need to determine not only the differences between how males and females of varying ages view themselves and their gender groups in terms of innate intelligence for engineering, but also what does this mean when associated with engineering.

Purpose

The purpose of this study is to initiate an investigation into the field-specific ability beliefs hypothesis in engineering and technology education so as to put forward an additional attempt at addressing gender disparities. In doing this, there is a clear need to determine what personal characteristics are associated with innate intelligence in the context of engineering, with specific emphasis on identifying potential characteristics which are dissociable between engineering and other fields. In previous work, Sternberg, Conway, Ketron and Bernstein (1981) examined the prototypical definition of intelligence in experts and laypeople. Both cohorts conceived intelligence as having three components. For experts these consisted of verbal intelligence, problem-solving ability, and practical intelligence while for laypeople consisted of practical problem-solving ability, verbal ability, and social competence. Interestingly, there were two common factors, verbal ability and problem solving ability, with a third factor differentiating the cohorts and reflecting a cohort specific form of practical intelligence describing a set of behaviours important specifically but not exclusively within each demographics cultural context. Subsequent work by Buckley et al. (2019) adopted the method used by Sternberg et al. (1981) in the context of STEM education with initial technology teacher education students. Similarly, the studied cohort also found intelligence in the context

of STEM education to consist of three components, termed social, general and technological competences. The general competence factor found by Buckley et al. (2019) largely mirrors the problem-solving ability factor found by Sternberg et al. (1981), with their social competence and verbal ability/intelligence factors also sharing some overlap. Interestingly, the third factor found by Buckley et al. (2019) also appears to be cohort specific and notably had the largest factor loading on the cohorts implicit theory of intelligence. Together, these studies add support for Sternberg's (1984) postulation of a 'common core' of intellectual functions which are culturally shared. In other words, that there are certain intellectual behaviours more associated with being human in general than with operating in any specific discipline. The purpose of this study is to instigate an investigation into determining both sets of intellectual functions for engineering, so as they can be studied in greater detail with non-practitioners.

Method

Approach and design

The method established by Sternberg et al. (1981) and subsequently adopted by Buckley et al. (2019) was utilised in this study. The entire method involves the use of two separate and sequential surveys, however this paper reports only the results from the first of these for this study.

In considering engineering as a single field to reflect the work of Leslie et al. (2015), two variables need to be considered particularly as it concerns gender disparities. First, there are a number of engineering fields, and they don't all display the same gender ratios. Taking the USA as an example, Yoder (2017) reported that in relation to 23 fields of engineering, at bachelor's level female representation ranged from 12.5% to 50%, at master's level is ranged from 13.6% to 45.7%, and at doctoral level it ranged from 10.7% to 48.7%. Therefore, while engineering is being considered as a singular, representation from a variety of engineering disciplines is important. Second, data from the Organization for Economic Co-operation and Development (OECD) indicates that the percentage of females enrolled in "engineering and engineering trades" education at bachelor's, master's and doctoral level ranges from 11.54% to 28.33% in OECD countries (OECD, 2019) suggesting that there is a cultural factor that needs to be explored. Therefore, it is necessary to consider multiple countries to explore cultural variances.

In the first survey, random participants from within a purposely selected cohort are first asked for demographic information to ensure alignment with the pertinent research question, and then asked giving a single request to list behaviours characteristic within intelligence in the relevant field. In this instance, the exact wording was "Please list all of the characteristics or qualities of a person you would describe as intelligent in the context of engineering". For the second survey, for which the data is currently being collected, the survey is sent to a random sample from within the same demographic of participants. The same demographic questions are asked, however this time the survey contains a list of each unique characteristic mentioned in the responses to the first survey, with participants being asked to rank each one on a 5-point Likert scale with the ratings "1 - Not important at all", "2 - Unimportant", "3 - Neither important nor unimportant", "4 - Important", and "5 - Very important". In this instance, the exact word used was "please rate how important each of these characteristics are in defining 'your' conception/understanding of an intelligent engineer".

Implementation and participants

Based on the 2016 OECD data (OECD, 2019), Sweden has the highest representation of female engagement with engineering in higher level education (28.33%), while Ireland has one of the lowest (14.13%). They were therefore selected as if a cultural effect is to be seen in terms of gender perceptions, they provide opportune contexts to explore it and to base future work in.

In Sweden, the first survey was sent to a random sample of 2000 engineering students in the country's largest university level engineering education provider. A total of 174 students responded to the survey ($M_{\text{age}} = 20.81$, $SD_{\text{age}} = 2.23$), of which 122 were male, 50 were female and 2 chose not to disclose their gender. The participants came from a variety of engineering sub-disciplines including 57 from IT and computer technology, 52 from mechanical engineering, industrial technology and finance, 14 from architecture, community building and construction technology, 13 from vehicle engineering, 11 from a common entry programme, 10 from energy and environment, 7 from electrical engineering, technical physics and applied mathematics, 6 from design and product development, 3 from technology and learning, and 1 from medical technology. Each participant was on a five-year long programme where the first three are at honours bachelor level and there is an automatic transition in year four to master's level for the final two years. Of the sample, 141 were in their first year of study, 29 in their second, 3 in their third and one respondent was in their fifth year.

In Ireland, the survey was sent to engineering students in two higher education institutions, one university and one institute of technology, to reflect the two types of providers of engineering education in the country. In the university, the survey was sent to approximately 600 students. A total of 85 students responded ($M_{\text{age}} = 20.51$, $SD_{\text{age}} = 3.18$), of which 65 were male, 19 were female and 1 chose not to specify their gender. The participants came from a number of different engineering sub-disciplines including 22 from mechanical engineering, 20 from engineering management, 18 from civil engineering, 11 from industrial engineering, 8 from biomedical engineering, 3 from product design engineering, 2 from aeronautical engineering, and 1 from electrical engineering. 80 of the participants were from honours bachelor's programmes, with 3 studying on ordinary bachelor's level programmes, and 2 studying at master's level. Finally, 28 participants were in their first year of study, 36 were in their second year, 7 were in their third year and 14 were in their fourth year.

In the institute of technology, the survey was sent to approximately 800 students. A total of 77 students responded ($M_{\text{age}} = 27.32$, $SD_{\text{age}} = 9.01$), of which 56 were male and 21 were female. 27 participants came from software engineering, 15 came from electronics and computer engineering, 11 from civil engineering, 8 from mechanical engineering, 7 from polymer engineering, 4 from quantity surveying, 2 from engineering management, 2 from mechatronics, and 1 from industrial engineering. 4 participants were studying on programmes where the degree award was a higher certificate, 26 students were studying on ordinary level bachelor's programmes, 42 were from honours bachelor's programmes, a further 4 were studying at master's level, and 1 participant was a doctoral candidate. Finally, 21 participants were in their first year of study, 17 were in their second, 19 in their third, 17 in their fourth and 3 were in their fifth.

Results

The first stage of the analysis involved coding each of the characteristics offered by participants. The list generated from the Swedish sample was initially coded with an inductive approach and subsequently the generated codes were used to deductively code the list generated by the Irish sample. A list of 683 characteristics ($M = 3.93$, $SD = 3.13$) was generated from the Swedish participants. A total of 445 remained once literal duplicates were removed. The characteristics were primarily coded by two members of the research team. Initially one researcher coded all of the data by manually collating each of the 445 characteristics into groups based on the similarity of their wording, which resulted in a total of 81 unique codes being created. A second researcher then reviewed each of the codes and commented on their uniqueness within the list. At this stage, the second researcher identified eight of the codes, i.e. four pairs, as synonyms. These were reviewed collectively by both researchers and four codes were revised to clarify their distinctions. For the second stage, the first researcher reviewed each of the characteristics they had coded again based on the revisions to the codes while the second researcher independently coded each of the 445 characteristics using the established coding scheme. When compared, there were 17

discrepancies indicating a 96.18% level of agreement between the researchers when applying the codes. Finally, a third member of the research team coded each of the 17 discrepancies to aid in assigning their final codes.

A similar process was conducted with the data from the Irish sample. A list of 619 characteristics ($M = 3.80$, $SD = 1.91$) were generated, with 342 remaining once literal duplicates were removed. Both the first and second researcher independently applied the coding scheme generated from the Swedish data to the list of 342 characteristics. When compared there were six discrepancies, indicated a 98.25% level of agreement. Both researchers agreed that there were 15 characteristics for which existing codes would not suffice. They collectively created 9 new codes, which the third researcher reviewed and confirmed. Therefore, a total of 90 unique codes, representing 90 unique characteristics of an intelligent engineer, were generated from the survey results (Table 1).

Table 4. Codebook with sample characteristics.

Code	Example statements
Ability to apply knowledge	Knowledge of how to apply what you have learned; Ability to apply theoretical knowledge to practical problems.
Ability to find relevant information	The ability to find information; Know where to find sought-after information.
Able to multitask	Good at multitasking.
Able to think abstractly	Abstraction; Good ability to think abstract; Able to abstract problems so that they become more gripable.
Able to understand complex information	Ability to understand complicated relationships; Understand so well that it can account for an understandable explanation; Able to decode information.
Adaptable	Adaptability; Adaptive; Can adapt; Flexible.
*Aggressive	Aggressive.
Ambitious	Ambitious.
Analytical	Analytical; Analytical ability; Break down complex systems into smaller components that can be more easily analysed.
Can make complex systems	Be able to create complicated systems.
Cautious	Prevention; Consider before doing anything.
Charismatic	Charisma; Charismatic.
Competent in mathematics	Good knowledge in mathematics; Good at mathematics.
*Competent in mechanics	Mechanics; Understanding of mechanics.
Competent in physics	Physicist; Basic knowledge in physics.
Competent in science	Mediation of science; Scientific.
Competent in technology	Good at technology; Technically talented.
Competitive	Competitive; Fighting spirit.
Confident	Self-confidence; Confident.
Craft skill	Good "craft" ability; Good practical skills.
Creative	Creativity; Creative thinking; easy to get many quick ideas others would call creative.

Code	Example statements
Creatively brave	Fearless to test solutions; Dare to stretch the boundaries.
Critical thinking	Source critical; Critical; Critical thinking.
Curious	Curious; Curiosity.
Decision making skills	Ability to make difficult decisions; Actionable; Good estimates.
Dedicated	Dedication; Dedicated; Perseverance.
Desire to learn	Constantly learn more/develop; The quest to always continue to learn/develop; Willing to learn; Develop their thinking for the better all the time.
Detail orientated	Meticulous; Accuracy; Eye for detail; Feeling for detail.
Determined	Determined; Determination.
Diligent	Documents the work carefully; Diligent.
Disciplined	Discipline; Disciplined; Focussed.
*Disorganised	Disorganised.
*Easily bored	Easy gets bored.
Economic	Economic.
Educated	Educated.
Efficient	Efficiency; Effective/efficient.
Empathetic	Ability to understand the needs of others; Can "get acquainted with the shoes of others" for understanding several perspectives.
Ethical	Can put their work in an ethical perspective; Morality.
Field specific knowledge	In-depth knowledge in the field; Knowledgeable in their field of work; Expertise in the subject area.
Foresight	Long-term-thinking; See problems before it arises
*Funny	Funny; Have a sense of humour; Witty.
General knowledge	Generally formed/generally knowledgeable; Broad knowledge.
Good at learning	Ability to effectively absorb new knowledge; Ability to familiarize themselves with new systems; Knowledge acquisition; Fast learner.
Good collaborator	Good at working in groups and projects; Collaborative.
Good communicator	Ability to communicate technology in an understandable way; Good communication; Communication skills.
Good social skills	Social skills; Socially competent; EQ; Social ability.
Good work ethic	Good work ethics; Productive.
Has a variety of areas of interest	Has one or more hobby, Likes to contribute in many areas.
Have a large contact network	Large contact network.
Healthy	Healthy.
*Honest	Honest.
Humble	Humble; Prestigeless.

Code	Example statements
Independent	Own thinking/Able to have own ideas; Independence; Self-propelled.
Intelligent	Whiz-kid; IQ; High IQ; Clever; Smart.
Interested in engineering	Deep interest in their area; Interested in their profession/area; Technically interested.
Intuitive	Intuitive; Strong intuition for the relevant subject.
*Lacking social skills	Lack of social skills.
Lazy	Lazy; Do not always study.
Leadership skills	Leadership.
Logical	Good on logical thinking; Logic; Rational.
Mature	Mature.
Methodical	Methodical; Structured; Systematic.
Motivated	Motivation; Motivated; Enthusiastic; Passionate; Driving.
Nerdy	Nerdy.
Nice	Nice; Friendly.
Open minded	Openness; Open to criticism; Open minded.
Organised	Determine how to plan; Ability to plan own work; Well prepared; Organized.
Pessimistic	Someone who is a bit pessimistic (good for prevention of errors).
Positive	Belief in the future; Positive; Positive towards challenges.
Practically orientated	Thing orientated; Inventive; Practical.
*Pragmatic	Hands on; Pragmatic.
Problem solving	Good problem solving ability; Good problem solver; Effective problem solving.
Quick thinking	Fast thinking; Quick; Quick ideas; Quick understanding.
Quiet	Quiet.
Realistic	Adds perspective in discussions; Realistic.
Reasonable	Reasonable; Can settle disputes.
Reflective	Reflective
Reliable	Reliable; Time-conscious; Consistent.
Resourceful	Resourcefulness; Improvisation ability.
Responsible	Responsible; Takes on great responsibility.
Self-aware	Knowing what it is you cannot do and then able ask someone who knows about help; Don't take on things that they cannot handle.
Self-control	Stress management; Patience; Stable; Maintains concentration even when not understood.
Solution orientated	Target focussed; Solution orientated; Impact thinking; Solution focussed.

Code	Example statements
Spatial ability	Spatial intelligence; Spatial understanding; Three and multidimensional thinking and visualizing.
*Strange	Strange.
Stressed	Stressed.
Stubborn	Stubborn.
Supportive	Helps and lifts (encourages) other workers; Supporting; Appropriate guidance; Unselfish.
Thoughtful	Thoughtful; Deep thinking.
Visionary	Vision; Can see an overall picture; Have future vision and see opportunities.

Note: * = Code created when coding the data from the Irish sample.

It is important to note at this point that in the full method, where both surveys are used, as the first survey dictates the design of the second each code is considered to be of equal importance regardless of its frequency of occurrence. However, as only the results of the first survey are presented, frequencies of codes are considered in this paper.

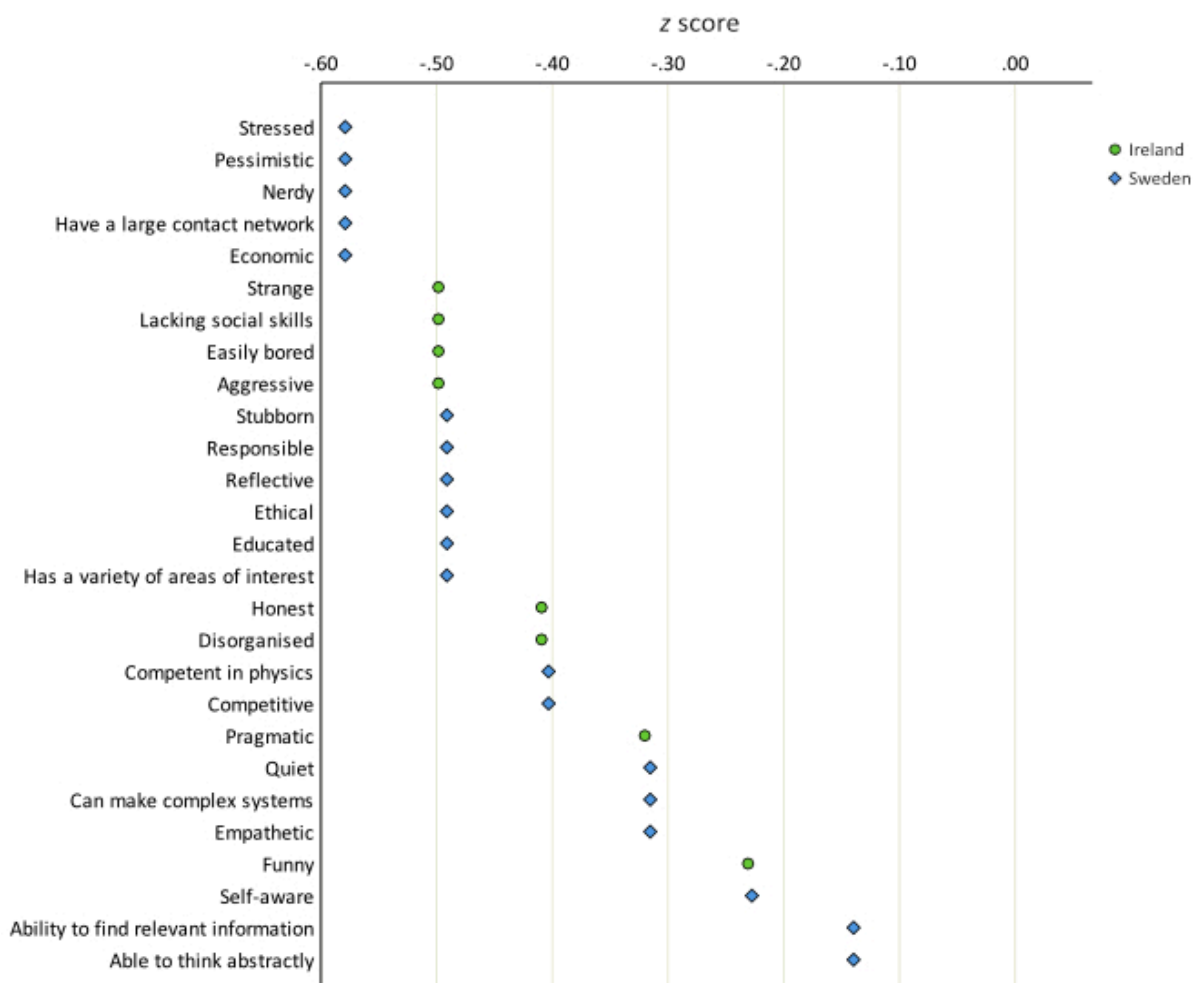


Figure 12. Frequencies of codes unique in both samples represented as z-scores.

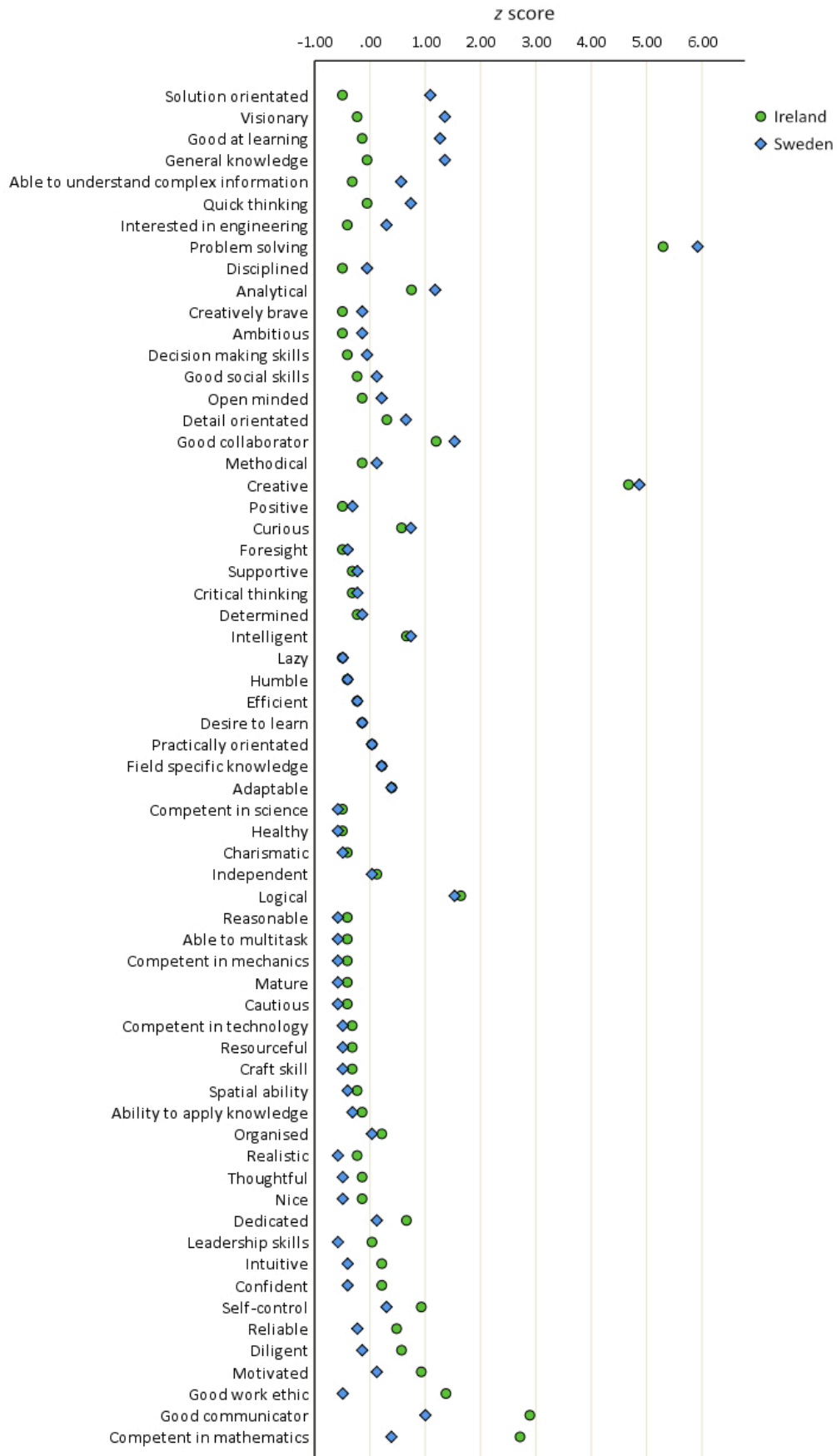


Figure 13. Frequencies of codes common to both samples represented as z-scores.

The frequencies of each codes were considered in terms of the complete lists of 683 characteristics from the Swedish sample and 619 from the Irish sample. In order to compare both lists frequencies were converted to z-scores. As both lists had different means and standard deviations, they were first transformed to have a mean of 0 and a standard deviation of 15. Figure 2 illustrates the frequencies of codes that were common in from both lists in terms of z-scores, and Figure 1 illustrates the unique codes from each sample in terms of z-scores.

Discussion

It is of most interest to consider the results from two related perspectives; how they relate to the previous work conducted by Buckley et al. (2019) and Sternberg et al. (1981) in terms of identifying engineering specific competencies, and what are the differentiating codes from each country.

In terms of the unique codes for each country, it should be noted from the position of frequencies that no unique code occurred a statistically significant number of times, i.e., there were no z-scores less than -1.645 or greater than 1.645. The codes primarily relate to personality characteristics, for example stressed, pessimistic, nerdy, economic etc. and considering the method, it is conceivable for an intelligent person to have any personality. Therefore, it is arguable that the codes associated with abilities are more important, of which there were none of from the Irish sample suggesting that data saturation was achieved with respect to the two cultures. In terms of unique abilities, the Swedish sample generated codes including “able to think abstractly”, “ability to find relevant information”, “can make complex systems”, and “competent in physics”. The first two of these are similar to codes found by Buckley et al. (2019) in that they relate to problem solving. The second two however are unique in comparison to both the work of Buckley et al. (2019) and Sternberg et al. (1981) suggesting competencies which may be uniquely considered to relate to engineering.

Considering the common codes, those that occurred a statistically significant number of times include “problem solving”, “creative”, “logical”, “good communicator” and “competent in mathematics” suggesting that these may have the strongest associations with engineering, however this does not mean that they are uniquely perceived as associated with engineering. When compared to the work of Buckley et al. (2019) and Sternberg et al. (1981), many of the codes theoretically fit the factors that they identified. The codes which appear unique to engineering seem to be associated with disciplinary knowledge, for example “field specific knowledge”, “competent in science”, “competent in mechanics”, “competent in mathematics” and “competence in physics”. When considered in relation to the technological competence factor observed by Buckley et al. (2019), this suggests that, from the perspective of implicit theories, the differentiation characteristic between technology and engineering is one of knowledge and not activity, as both datasets emphasise general problem solving and creativity. Potentially, although it cannot be confidently inferred from this data, the type of activity may also be implicitly perceived to be different, as craft was seen as important in a technological context whereas it has a low frequency in the current dataset. The results of the second survey will add additional empirical data for which to deduce this from.

Finally, the frequencies of the common codes suggest a cultural difference in the perceptions of intelligent engineers. Based on the frequencies, Swedish participants were more likely to associate intelligent engineers with general competencies such as being “solution orientated, visionary”, “good at learning” and having “general knowledge”. However, the biggest difference in terms of a high frequency from the Irish participants was to associate an intelligent engineer with someone who is good at mathematics. The second biggest difference in this regard was the frequencies for the “good communicator” code, suggesting that for the Irish participants, communication was a more important trait for an engineering than what was perceived by Swedish participants.

In conclusion, the results of this study suggest that engineering likely has a unique characteristic in terms of engineering competency, and that is it probably knowledge based and the interpretation of craft in engineering education may be different to that in technology education. In terms of future work regarding gender differences, this suggests that exploring young girls' self-perceptions in terms of engineering specific competencies may be possible, which could significantly impact efforts to address the gender disparity in the field.

References

- Bian, L., Leslie, S.-J., & Cimpian, A. (2017). Gender stereotypes about intellectual ability emerge early and influence children's interests. *Science*, *355*(6323), 389–391.
- Blackwell, L., Trzesniewski, K., & Dweck, C. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development*, *78*(1), 246–263.
- Buckley, J., O'Connor, A., Seery, N., Hyland, T., & Canty, D. (2019). Implicit theories of intelligence in STEM education: Perspectives through the lens of technology education students. *International Journal of Technology and Design Education*, *29*(1), 75–106.
- Cheryan, S., Meltzoff, A., & Kim, S. (2011). Classrooms matter: The design of virtual classrooms influences gender disparities in computer science classes. *Computers and Education*, *57*(2), 1825–1835.
- Cheryan, S., & Plaut, V. (2010). Explaining underrepresentation: A theory of precluded interest. *Sex Roles*, *63*(7–8), 475–488.
- Cheryan, S., Plaut, V., Davies, P., & Steele, C. (2009). Ambient belonging: How stereotypical cues impact gender participation in computer science. *Journal of Personality and Social Psychology*, *97*(6), 1045–1060.
- Dar-Nimrod, I., & Heine, S. (2006). Exposure to scientific theories affects women's math performance. *Science*, *314*(5798), 435.
- Kirkcaldy, B., Noack, P., Furnham, A., & Siefen, G. (2007). Parental estimates of their own and their children's intelligence. *European Psychologist*, *12*(3), 173–180.
- Leslie, S.-J., Cimpian, A., Meyer, M., & Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science*, *347*(6219), 262–265.
- Miller, D. I., Eagly, A. H., Linn, M. C., Miller, D. I., Eagly, A. H., & Linn, M. C. (2014). Women's representation in science predicts national gender-science stereotypes: Evidence from 66 nations. *Journal of Educational Psychology*, *107*(3), 631–644.
- Neisser, U. (1979). The concept of intelligence. In R. Sternberg & D. Detterman (Eds.), *Human Intelligence: Perspectives on its Theory and Measurement* (Vol. 3, pp. 179–189). New Jersey: Ablex.
- OECD. (2019). OECD.Stat: Enrolment by field. Retrieved October 8, 2018, from <https://stats.oecd.org/#>
- Rosch, E. (1977). Human categorization. In N. Warren (Ed.), *Studies in Cross-cultural Psychology* (pp. 1–49). London: Academic Press.
- Rosch, E., & Mervis, C. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology*, *7*(4), 573–605.

- Rosch, E., Mervis, C., Gray, W., Johnson, D., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, 8(3), 382–439.
- Sternberg, R. (1984). A contextualist view of the nature of intelligence. *International Journal of Psychology*, 19(3), 307–334.
- Sternberg, R., Conway, B., Ketron, J., & Bernstein, M. (1981). People's conceptions of intelligence. *Journal of Personality and Social Psychology*, 41(1), 37–55.
- Sultan, U., Axell, C., & Hallström, J. (2018). Girls' engagement in technology education: A systematic review of the literature. In N. Seery, J. Buckley, D. Canty, & J. Phelan (Eds.), *PATT36 International Conference: Research and Practice in Technology Education: Perspectives on Human Capacity and Development* (pp. 231–238). Athlone, Ireland: Technology Education Research Group.
- Swim, J., Aikin, K., Hall, W., & Hunter, B. (1995). Sexism and racism: Old-fashioned and modern prejudices. *Journal of Personality and Social Psychology*, 68(2), 199–214.
- Swim, J., & Cohen, L. (1997). Overt, covert, and subtle sexism. *Psychology of Women Quarterly*, 21(1), 103–118.
- Swim, J., Mallett, R., Russo-devosa, Y., & Stangor, C. (2005). Judgments of sexism: A comparison of the subtlety of sexism measures and courses of variability in judgments of sexism. *Psychology of Women Quarterly*, 29(4), 406–411.
- Tiedemann, J. (2000). Gender-related beliefs of teachers in elementary school mathematic. *Educational Studies in Mathematics*, 41(2), 191–207.
- Valian, V. (1998). *Why so slow? The advancement of women*. Cambridge, Massachusetts: MIT Press.
- Wang, M., & Degol, J. (2017). Gender Gap in Science, Technology, Engineering, and Mathematics (STEM): Current Knowledge, Implications for Practice, Policy, and Future Directions. *Educational Psychology Review*, 29(1), 119–140.
- Wigfield, A., & Eccles, J. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology*, 25(1), 68–81.
- Yeager, D., & Dweck, C. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist*, 47(4), 302–314.
- Yoder, B. (2017). *Engineering by the numbers*. Retrieved from <https://www.asee.org/documents/papers-and-publications/publications/college-profiles/2017-Engineering-by-Numbers-Engineering-Statistics.pdf>

Inducting ITE students in assessment practices through the use of comparative judgment.

Donal Canty, Jeffrey Buckley, Niall Seery



Donal Canty
University of Limerick

Ireland
donal.canty@ul.ie



Jeffrey Buckley
Athlone Institute of
Technology, KTH Royal
Institute of Technology

Ireland, Sweden
jbuckley@ait.it



Niall Seery
Athlone Institute of
Technology

Ireland
nseery@ait.it

ABSTRACT

A new curricular framework, presented by the Department of Education and Skills (DES), (2015) implements an assessment strategy that has changed from a predominantly summative to a more formative integrated approach. With the emphasis being placed on the process of learning rather than the product, it is critical that the assessment practices and instruments created and employed by the teacher have the capacity to capture authentic evidence of student learning and capability for the purpose of both formative and summative assessment. The tensions between formative and summative assessment outlined by Black and Wiliam (1998) raise considerable concerns for teachers and learners. Striking a balance between the forms of assessment and their impact on teaching and learning is of critical importance. This also has implications for Initial Teacher Education (ITE) where undergraduate teachers endeavour to become literate and skilled in assessment. This paper focuses on a strategy that uses peer assessment, facilitated through comparative judgment (Kimbell, 2011), to help student teachers identify qualities of capability, establish constructs of quality and standards and develop skills in generating formative commentary that will help move the learner forward. This paper describes an explorative case study that observes the practices and outcomes of student teachers as they engage in assessment related tasks. The study tracks 59 Technology ITE students as they respond to a learning and assessment task, establish criteria and standards for assessment, and generate formative feedback for learners. Data collection for the study will be predominantly qualitative in nature focusing on the outputs student teachers made in relation to delivering effective formative feedback on a learning and assessment task. Quantitative data from the comparative judgement assessment instrument will give further insight into the assessment practices of the participants on an individual and group level. The results of this study will present an analysis of the nature and quality of the feedback created by the student teachers highlighting potential gaps in the knowledge and skills required to deliver effective feedback in the classroom setting.

Key Words: Formative assessment, comparative judgment, feedback, peer assessment

Introduction

The Irish second level education system is going through a period of significant curricular reform. This is being conducted in two phases, the first of which is a reform of the curricular provision at lower post-primary level, i.e. Junior Cycle. The nature and structure of the new approach to Junior Cycle education was outlined by the Department of Education and Skills (DES) in 2015. This document presented a new focus on key skills and attributes that are now central to teaching learning and assessment. The reform also placed emphasis on the need for pedagogies and teaching styles that are more student centred where it is now expected that students take a more central role in their learning (DES, 2015). 2019 will see the introduction of new specifications in the technology subject domain. A suite of four technology related subjects will be rolled out each making its own contribution to the development of technological capability and literacy. A central element to the new reform is the way in which learners will be assessed and the role that the teacher will play in the assessment process. The new curriculum places emphasis on assessment as a more integrated part of teaching and learning. Traditionally the emphasis of assessment has been on summative practices with the teacher's role in the assessment being focused on the preparation of the student for the examination or testing process. The new approach encourages a classroom where learners are supported in the acquisition and application of knowledge and where teacher planning is focused less on examination preparation and more on collaborative planning for teaching and learning (DES 2015). The model of assessment at Junior Cycle level sees a dual approach implemented that involves both classroom-based assessments (CBA's) and a summative assessment that is externally set and assessed by the State Examinations Commission (SEC).

The introduction of CBA's is new in the Irish context and it is the first time that teachers are required to pass judgment on their students that will be recorded as part of the state certified Junior Cycle Profile of Achievement (JCPA) award. Two CBA's will be carried out during regular class time, one in year 2 and the second early in year 3 of the cycle. The nature of the CBA's is to be both formative and summative, providing teachers and pupils with a snapshot of where the pupils are in their learning and identifying critical aspects of their skills and capability that they will need to work on such that they can realise their full potential in the relevant subject and discipline area. This change from a predominantly summative to a more formative integrated approach brings with it challenges for teachers and teacher education providers.

The new assessment approach through the CBA activities requires the teacher to plan and implement teaching, learning and assessment activities that will generate evidence of learning. This evidence, and any conclusions that will be drawn from it, will serve three functions. The first is to provide a benchmark of student ability at a particular point in the junior cycle. Teachers will have to make a judgment on learners work presented in the CBA, mapping it onto features of quality (that will be set by the National Council for Curriculum and Assessment, NCCA) and resulting in an output at one of four level descriptors: (1) Yet to Meet Expectations, (2) In Line with Expectations, (3) Above Expectations and (4) Exceptional. The second is that the evidence gathered through this CBA activity will be used to inform the learner and their parent/guardian of their progress to date and provide them with formative feedback on both their current level of ability and potential future actions that will help them progress. The third purpose is that the CBA activity will inform the teacher in relation to their learners' ability and progress such that they can plan future pedagogical strategies and/or interventions that will address any gaps or deficiencies illuminated through the CBA. This paper focuses on one element of a larger study that looks at how teachers and learners are engaging with and experiencing all three purposes or functions described above. The perspective of this paper will look at the preparation of Technology ITE students to engage with the second function of the CBA where teachers will have to provide formative feedback to learners to help them move forward in their learning. This challenge is significant for Technology ITE students as the nature of technology related activity is often diverse and non-routine requiring teachers to give feedback that is constructive in moving the learning forward

but without being leading or prescriptive. This study posed the question: What is the nature of the feedback Technology ITE students generate in relation to a CBA task and does comparative judgment present opportunity for Technology ITE students to develop knowledge and skills that will benefit them in future assessment practice in their classroom?

Theoretical Framework

The role and value of formative assessment in any educational transaction is well documented. 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. Yorke (2003), Orsmond et al. (2000), Sadler (1998; Sadler 2009) and Black and Wiliam (1998) present the teacher, peers and the student 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. To this end Technology ITE students must become aware of the significance of effective integration of assessment as part of the planning for learning process and develop a skillset that will help them draw inference and effectively communicate their evaluation and judgment on the evidence of learning from the CBA. The role of the learner and the need for the development of appropriate assessment skills such as the capacity to self-assess and judge quality, receive and interpret feedback and set goals based on feedback are acknowledged as being a significant and integral part of the assessment process but are beyond the scope of this paper. Thus the focus will be on the Technology ITE student and preparing them for their classroom practice. To this end the following elements were addressed in the study:

Qualities: To generate quality feedback the teacher must first have a sound knowledge of the construct of interest for the technology discipline and which relates to the features of quality set out by the NCCA. Developing this construct must form part of the assessment strategy and is central to the skillset required for effective integration in teaching and learning as it leads to better understanding of the qualities that should be evaluated and measured.

Evidence: Teachers must recognise the role of the assessment instrument to capture and present authentic evidence of learning and capability in the technology subject discipline. There must be an awareness of how such instruments can negatively impact on teaching and learning often leading to formulaic, routinized and predictable outcomes as they align rigidly with assessment criteria reducing the process to nothing more than a box ticking exercise (Kimbell et al. 2004). With the new technology curricula operationalised through design-based activities, where there is a need to acquire relevant multi-disciplinary knowledge, demonstrate capability, evolve problem solving skills, effectively communicate, and synthesise information and conceptions, the teacher must establish how they can create the opportunity for the above to happen while also gathering evidence of the learning for the purposes of assessment.

Judgment: For a teacher to make judgements about the quality or standard of work they must have a reasonable idea or feel for the standards they intend to apply (Sadler 2005). Kimbell (2007) outlines how the assessor can begin to make sense of quality and criteria with the introduction of exemplars for comparison helping to normalise the criteria making them meaningful for the assessor. Developing the capacity to discriminate quality is a critical skill for the teacher when the requirement to deliver formative feedback to the learners is a central goal.

Generating formative feedback: To be effective feedback must provide opportunities to close the gap in relation to where the learner is judged to be and where they need to get to. Hattie (2011) presents Hattie and Temperley's model of feedback that focused on three central questions that learners need to address if feedback is to be effective: Where am I going? How am I going?, and Where to next? To navigate this space teacher feedback should help the learner to orientate themselves in terms of quality and approach and potentially guide them in relation to setting goals for future action relating to progressing their learning. Four levels of

feedback are presented by Hattie & Timperley (2007): Task or Product level, Process level, Self-regulation level and The Self. Determining which level of feedback to give is dependent on the learner and the context of the task. Developing the capacity to create formative feedback at the individual levels and understanding the context in which to action it is a key skill for the teacher.

This study presents an analysis of the formative feedback created by Technology ITE students that was intended to address the three feedback related questions presented by Hattie & Temperley 2007. It also examines, from the Technology ITE student's perspective, the process of giving and receiving feedback as part of the learning and assessment process.

Method

The participants in this study (N=59) were in their third year of a four year undergraduate concurrent technology teacher education programme. All participants had completed an eight week school placement in the previous semester where they had developed basic skills in assessment of and for learning. This study was conducted in a module of learning for the Technology ITE students and was structured around the four elements outlined above.

This study utilised a mixed methods approach collecting both qualitative and quantitative data. The approach presented three data collection points. The first is the statistical data relating to the comparative judgment (CJ) assessment activity. This data is quantitative in nature and presents the level of consensus and reliability in the decision making process by the student teacher assessors. The second and third data sets are qualitative in nature and were used to uncover the nature of participant's formative feedback and well as to document their experiences of engaging with the assessment activity. The second data set is the formative feedback comments that the student teacher judges made in relation to the work that they evaluated and judged as part of the CJ assessment. This data was analysed and mapped onto the four levels of feedback presented by Hattie and Temperley (2007). This analysis was conducted using a deductive approach, where after an initial training period using 10% of the data, one researcher and one member of academic staff working on the ITE module both coded the remaining 90% on the levels of feedback presented by Hattie and Temperley (2007). The third data set is the student teacher responses to a qualitative questionnaire that was administered to help gain insight into their experiences of the CJ assessment activity and generation of formative feedback. This data was again analysed deductively, however this was done using Braun and Clarke's (2006) six-stage framework.

The following section presents how each element was approached and delivered. This paper will then focus on the output from the fourth element of the approach.

The initial phase of the module engaged students in the co-construction and development of features of quality and level descriptors to align with the curriculum goals. Students then devised a CBA activity intended to provide the opportunity to achieve the features of quality.

The second phase involved the ITE students designing an assessment instrument that would facilitate both teaching and learning and capture evidence of learning for assessment. This was developed iteratively with support and feedback from the academic team. The students then used this instrument to complete the CBA task generating evidence of capability that they presented in portfolio format for assessment.

The third phase used comparative judgment software to provide Technology ITE students with the opportunity to holistically judge a range of portfolios from the class cohort. Through the CJ approach students were exposed to a range in quality of portfolios and were required to decide on which one was better in terms of quality. This resulted in a rank order of the work being created and the level of agreement/disagreement of the class group on the quality of the work being recorded. For more information on the CJ process please see Kimbell 2011.

The fourth and final phase occurred during the CJ session. When ITE students judged the portfolios they also generated formative comments that were intended for the learner that created the piece of work. This was recorded by the software and returned to the individual learner when the judging session was complete.

Findings

All 59 participating students completed the CJ assessment activity achieving a Cronbach alpha reliability coefficient of 0.68.

Figure 1 and Figure 2 present the level of mis-fit recorded for both judges and portfolios. This was low with only 1 judge and two portfolios outside the mis-fit criterion. For more information on mis-fit criteria see Kimbell et al. 2009.

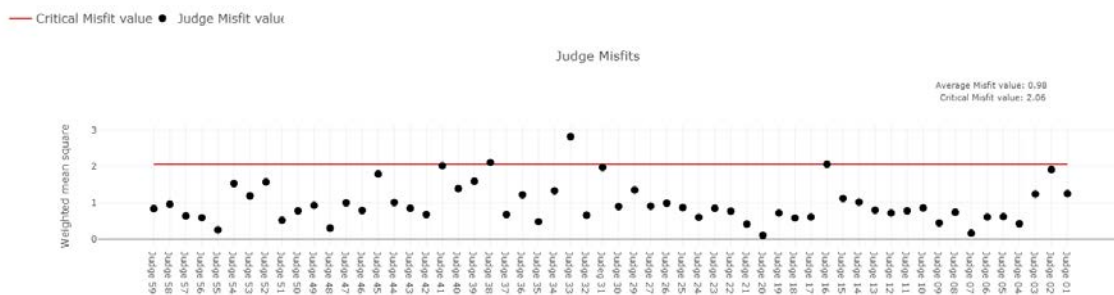


Figure 1: Judge mis-fit statistics

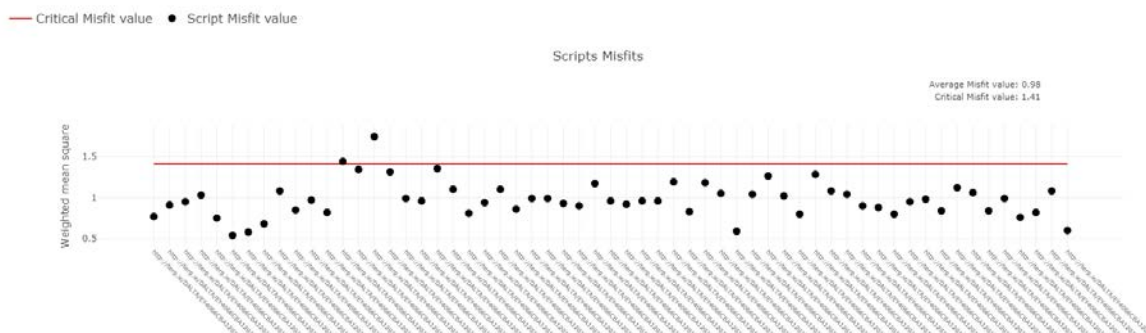


Figure 2: Portfolio (Script) mis-fit statistics

Student responses to the questionnaire

Table 1: Percentage of student responses per category

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Completing the judging session was a beneficial learning activity for this project	68	27	5	0	0
Receiving feedback from my peers benefited me in my learning	53	41	3	3	0
Giving feedback to my peers benefited me in my learning	54	44	2	0	0

Overall the students found the CJ process to be quite helpful. Some indicative comments from the questionnaire instrument are presented here:

Participant 16: *The comparative judgements I feel was a great way to grade my peers work. It gave a broad spectrum of the different types of CBAs and how people can interpret them. It allowed me to assess in detail different types of CBAs but was flexible in the terms that no CBAs were similar because of the no 'set criteria' for the project.*

Participant 20: *I feel this is a great tool as we more than likely would not have received this amount of feedback if it was just from one assessor. I feel this gives us more feedback and also different opinions on our CBA which is something that you want when you receiving feedback.*

Participant 28: *I really enjoyed the experience. It was very interesting to see the different approaches that my peers took. I feel the task was very valuable as it gave us an insight into what it will be like to guide our future classes through a CBA and then assess the work afterwards.*

Participant 40: *Overall, I found the experience an enlightening one. I learned more about the process of providing formative feedback which will prove extremely useful for my 4th year teaching practice and of course the rest of my career as a future educator.*

Participant 50: *Very good practice. Comparing mine I would say it was quite poor. Some of others work was exemplary and very innovative. It shows where we stand in the terms of effort put in. It was good to have the comparisons in the first section of the module so that we have good incentive to work harder, and have a chance to progress at a better standard.*

Preliminary analysis of formative feedback generated by students

Students generated 645 formative comments in relation to the work that they evaluated and judged. The comments were in paragraph form and were generally written in a format that was directed at the learner.

The comments were analysed and mapped onto the four levels of formative feedback presented by Hattie and Temperley (2007). Table 2 presents the categorisation that emerged.

Table 2: Categorisation of feedback

	Task Level	Process Level	Self-Regulation	The Self
Percentage of comments per category	51	95	8	1

Discussion & Conclusion

At the heart of this study was the use of comparative judgment (CJ) as a medium to provide ITE students with the opportunity to action their construct of quality in relation performance in a classroom based assessment activity and to provide constructive formative feedback intended to help learners close the gap between current performance and desired standards.

The CJ process was completed with a Cronbach alpha reliability coefficient of 0.68. This indicates a reasonably high level of consensus among the novice student judges in relation to the rank order of the quality of the work. Only one judge and two portfolios were outside the misfit criterion. This indicates that decisions in relation to the portfolios aligned and that most

judges made similar decisions. It should be noted that this is not indicative of validity of the rank. The validity of the rank is determined by mapping the qualities and position of the portfolios onto the features of quality set out by the NCCA. This is part of the larger study referenced earlier and is beyond the scope of this paper. The identification of outlier portfolios presents opportunity to engage in dialogue around assessment with the group of assessors to try and establish the unique factors that may have contributed to the disagreement on the work that was evaluated. This is helpful when initiating and engaging the Technology ITE students in these conversations as it is the group themselves that have generated the disagreement. Highlighting the mis-fit judge(s) is beneficial in that it provides insight on judges that seems to have misaligned with the consensus of the group providing opportunity for further intervention to address potential needs of the judge.

It is clear from the responses of the group of ITE students that they gained benefit from engaging in the CJ assessment process. Table 1 presents the significant levels of agreement that giving and receiving feedback had a positive impact on learning in the module. The initial analysis of the responses to the questionnaire, identify a number of themes that can be seen in the indicative comments presented. Students felt that it broadened their concept of quality and also provided them with a broad range of feedback from multiple judges that was helpful in them progressing their work. They also indicated that the process helped them develop a better understanding of effective feedback and that it promoted self-reflection on their own work and progress.

One of the seven principles of good feedback presented by Nicol & MacFarlane-Dick (2006) is that feedback should facilitate the development of self-regulatory skills in learners. This study has identified that a significant body of the ITE students that generated feedback on the work did not generate feedback at the self-regulative level. This does not indicate that they are not capable of generating such feedback, but it does highlight that they did not consider this level as being important when they created their feedback for the learner. This analysis has itself identified a gap in the knowledge and skills of the ITE students which presents opportunity for an intervention that can help address this issue. This intervention was enacted following the data analysis but was not completed in time for this publication. The outcomes of this intervention will be the subject of future work in this area.

In conclusion this study indicates that the use of comparative judgment had a positive impact on the Technology ITE student's learning about assessment practice. However, analysis of the feedback generated through the CJ process has revealed that the nature of the feedback is predominantly at the task or process level thus providing the opportunity for an intervention to create more awareness of the need for feedback at the self-regulative level.

References

- Black, P. and Wiliam, D. (1998). Assessment and classroom learning, *Assessment in Education: Principles, Policy & Practice*, Vol. 5, Issue 1
- Braun, V. and Clarke, V. (2006). Using thematic analysis in psychology, *Qualitative Research in Psychology*, 3:2, 77-101
- Department of Education and Skills (2015). Framework for Junior Cycle. Dublin, Ireland: Published by the Department of Education and Skills.
- Hattie, J. (2011). Feedback in Schools. In Sutton, R., Hornsey, M.J., & Douglas, K.M. (Eds., 2011), *Feedback: The communication of praise, criticism, and advice* (pp. 265-278). Peter Lang Publishing: New York.
- Hattie, J, Timperley, H (2007). The power of feedback. *Review of Educational Research*, 77(1), 81-112.
- Kimbell, R. (2007). "E-assessment in Project e-scape." *Design and Technology Education: An International Journal* 12(2).
- Kimbell, R. (2011). "The origins and underpinning principles of e-scape." *International Journal of Technology and Design Education* **Published online: Jan 2010.**
- Kimbell, R., Stables, K., Wheeler, T., Miller, S., Bane, J. and Wright, R. (2004). Assessing Design Innovation. London, Department of Education and Skills.
- Kimbell, R., Wheeler, T., Stables, K., Shepard, T., Pollitt, A., Martin, F., et al. (2009). E-scape portfolio assessment phase 3 report. London, TERU: Goldsmiths University of London.
- Nicol, D.J. and Macfarlane-Dick, D. (2006) 'Formative Assessment and Self-Regulated Learning: A Model and Seven Principles of Good Feedback Practice', *Studies in Higher Education*, 31(2), 199-218.
- Orsmond, P., Merry, S. and 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. (2005). "Interpretations of criteria-based assessment and grading in higher education." *Assessment & Evaluation in Higher Education* 30(2): 175 - 194.
- Sadler, D. R. (2009). Transforming Holistic Assessment and Grading into a Vehicle for Complex Learning. *Assessment, Learning and Judgement in Higher Education*. G. Joughin, Springer Science+Business Media: 45 - 63.
- Yorke, M. (2003). "Formative assessment in higher education: Moves towards theory and the enhancement of pedagogic practice." *Higher Education* 45(4): 477 - 501.

Integrative STEM Education - A New M.Ed. Program: Development, Objectives, and Challenges.

Osnat Dagan, Noa Ragonis, Daphne Goldman, Tili Wagner



Osnat Dagan
Beit Berl College
Israel
osnat.dagan@beitberl.ac.il;



Noa Ragonis
Beit Berl College
Israel
noarag@beitberl.ac.il



Daphne Goldman
Beit Berl College
Israel
dafnag@netvision.net.il



Tili Wagner
Beit Berl College
Israel
tiliw@beitberl.ac.il

ABSTRACT

Beit Berl College received approval to develop an integrative master's degree program in Science, Technology, Engineering, and Mathematics (STEM) Education, aiming to train educators to design and implement STEM curricula in schools and other educational settings in Israel. The program is currently under development and is due to be launched during the 2021 academic year. The main goals of the program are to expand and enrich the teachers' understanding of the different STEM-based fields, introduce them to new integrative fields implemented in industry and academia, and provide them with the necessary foundations for implementing integrative STEM education using cutting-edge teaching and learning techniques. The preparation of teachers motivated and able to attract students and implement integrative STEM curricula is a challenge worldwide, and in Israel, for two main reasons. First, most teachers hold a degree and teaching certificate in a single specific discipline, and working collaboratively across disciplines is rare. Second, most Math and Science teachers lack technology and engineering foundations. The program core will be based on problem-solving thinking and action in the framework of Project Based Learning. Students will be educated to design and provide solutions to problems using approaches similar to those that are conducted in industry and academia. These include working in multidisciplinary teams, through the design process, where members bring expertise from their respective bachelors' degree fields and together develop innovative, creative, and implementable solutions. The paper presents the scientific and educational background underlying the program, and the program rationale, goals, objectives, and main principles that guide its development. Dilemmas and challenges in the development stage and in the expected implementation are addressed, and will be discussed during the conference.

Key Words: STEM Education, Integrative, Problem Solving, Teamwork, Teacher Professional development, Design Thinking

INTRODUCTION

In the 21st century schools need to prepare students for a rapidly changing world in which information is increasing, where many professions combine different disciplines, and where teamwork is a necessary condition for addressing needs, solving problems, creative and critical thinking, and initiating and implementing new ideas (Bybee, 2013). These competences are crucial for people as citizens and for taking part in the workforce. This need is reinforced in relation to the integration of Science, Technology, Engineering, and Mathematics (STEM) in both academia and industry that report a shortage in recruitment of students and employees possessing these capabilities. This shortage originates in high schools, where pupils first choose a possible path of expertise, and teachers have a key influential role in this decision. The education system's responsibility is to advance school graduates in these contemporary and vital directions (Joyce & Dzoga, 2013). The situation in most countries, including Israel, is that most teachers hold a degree in a single discipline and are inexperienced in developing cross-disciplinary and collaborative learning collaboratively for their pupils. Additionally, many of the math and science teachers lack foundations in technology and engineering. To address 21st century challenges, as well as the teachers' professional development challenges, the Israeli Council for Higher Education approved the development of an integrative master's degree program in STEM Education to train skilled and motivated educators to design and implement interdisciplinary STEM education curricula. The aim is to meet the need for developing educators' knowledge and skills at the level of a graduate program in order to enable valuable change in the field. To address the challenges of developing a program with broad vision, an interdisciplinary development-team was established in Beit Berl College (the paper's authors), and several consultation meetings with scientists and industrialists were held in order to deepen and sharpen the goals and contents of the program.

BACKGROUND

STEM (Science, Technology, Engineering, and Mathematics) – the gap

The term STEM has been used in the education arena from the 1990s, and the community embraced this slogan. Practically, STEM is usually interpreted to mean science or mathematics, only seldom does it refer to technology or engineering. Literature indicates various ways to integrate these subjects. Dugger (2010) mentioned three ways: a) to teach each of the four STEM disciplines individually, teaching each discipline as an independent subject with little or no integration to the other subjects; b) to teach each of the four STEM disciplines with more emphasis on one or two of the four (Science and Math); and c) to integrate one of the STEM disciplines into the other three being taught (engineering to science, technology, and math). There are increasing arguments that learning processes in schools and higher education are not focused enough on the interdisciplinary integration of science, engineering, technology, and math. In response to this, different STEM curricula and initiatives have been developed and implemented (Bybee, 2013; Cagle, Caldwell, & Garcia, 2018; Sanders, & Wells, 2006). Schools have the role to prepare students for an unpredictable world, in which there are interdisciplinary professions, and teamwork is crucial for problem solving, initiating innovative ideas and implementing them. Effective integrative STEM education could increase students' understanding of how things work, improve their understanding and use of technologies, and develop their innovation and problem-solving abilities. This is the contribution of technology and engineering to STEM subjects (Bybee, 2010). The holistic problem-solving process, as a core element that enables the integration of subjects, has a reciprocal contribution. The engineering area can contribute to the thinking and problem-solving processes while developing challenging projects that include various disciplines, while working in teams, implemented, and assessed in real life (Bybee, 2013).

Master's degree in STEM education

Academic programs in integrative STEM education do not exist in Israeli higher education (HE) in bachelor or graduate levels. There are master's degrees in Education Research programs that focus on the teaching of a specific discipline such as Biology, Computer Science, or Electricity. A review of master's degree programs in the USA and EU shows that most of them, similar to Israel, teach each discipline separately. Some unique integrative STEM education master's degree programs exist in the U.S. for example at Hofstra University, Virginia Polytechnic University, and University of San Diego. In those programs, the emphasis is on the integration of technology and engineering with the sciences and math.

The STEM education master's programs are varied in their content, disciplinary integration, and teaching methods aspects (Cagle et al., 2018). These programs' goals include (Bybee, 2013; Hanover Research, 2011; Joyce & Dzoga, 2013, Mayes, Rittschof, Gallant, & Marti, 2017):

1. Training the learners with high abilities to cope with the 21st century challenges and opportunities.
2. Increasing the effectiveness of the education systems in developing a society that is literate in STEM areas.
3. Providing tools, skills, and competences for using information in order to identify real life problems, which will enable them to explain the natural and artificial worlds and present conclusions based on data in STEM issues.
4. Understanding the STEM discipline's characteristics as forms of knowledge, inquiry, and design.
5. Developing creative use of the mathematic, scientific, and technological concepts through implementing them in engineering design and development.
6. Establishing infrastructure for developing innovative research and marketing.

Various studies have found that despite the differences among the STEM programs in their goals and structure, the STEM programs contribute to the learners' interest, curiosity, motivation, learning, and skills awareness (Dugger, 2010; Figliano, 2007; Fulton & Britton, 2011; Howarth & Scott, 2014; Lynch, 2012; Wolterm, Lundeberg, & Bergland, 2013). Research emphasizes that learning should be conducted through case studies in which the various disciplines are expressed, and the contexts and parallels are explicitly presented and implemented (Klaassen, 2018).

Teachers are a key point and need to be trained as educational leaders aligned with the vision and principles of integrative STEM education. Accordingly, appropriate teaching methods for use in schools and higher education are being examined; for example, implementing evidence-based research in relation to teaching practices in STEM (Milner-Bolotin, 2018).

Problem/Project Based Learning

A key organizing element of STEM programs is the implementation of Project-Based Learning (PBL) in teams, where the choice of problems is significant, and should relate to the real-world and require conceptual understanding, along with alternative solutions that cultivate the development of significant skills (Reinholz et al., 2018). PBL includes presenting an authentic problem with its requirements and constraints. During the project, alternative ideas for solving the problem will be raised, criteria for choosing the most appropriate solution will be developed, the appropriate solution will be chosen, and the product will be made. PBL is a pedagogical method whose main aim is to cultivate active learners that develop and work in teams, while collecting the needed information for solving the project problems. The teachers, in this learning method, are coaches and mediators (Tseng, Chang, Lou, & Chen, 2013).

STEM literacy that is built on PBL is very important for all students and is identified as a "Meta Discipline" (Zollman, 2012). Learning in the PBL method provides authentic content and

context-related experience that are crucial to the learner, and is used as a scaffolding system that supports construction of meaningful and effective learning in sciences, technology, engineering, and math (Capraro, Capraro, & Morgan, 2013). Engineering design is a central pillar in STEM PBL, the learners use their knowledge in science, technology, and math while solving real life open-ended and ill-defined problems (Capraro & Slough, 2013). This learning method forces the learners to use critical, analytical, and synthesis thinking, and evaluation and reflection on their problem-solving process (Capraro & Slough, 2013). PBL in STEM could bring learners closer to these subjects, evoke their interest, and motivate them to deal with them. Selection of the problems for PBL is significant. They should be relevant to real life situations; enable conceptual understanding, include various subjects, be ill-defined, have a few ways to solve them, and a few solutions; and integrate meaningful competences (Reinholz et al., 2018).

For teaching PBL there is a need of professional teachers that have the necessary skills for planning and developing learning experiences. Therefore, the teachers, themselves, must receive high quality professional training and development.

The ability to work in teams is very important, especially in PBL, in which combining different areas of knowledge is crucial. Each participant in a team is an expert in his/her field, but also could and should understand the tools available in the other fields and their potential contribution to addressing the problem. Multidisciplinary teams also better enable achieving innovative ideas and solutions.

Education and values in teaching STEM

Many learners do not see how science can be relevant to their lives, especially when the science curriculum in Israeli high schools focuses mainly on the core disciplines' aspects. Therefore, there is a need to add relevant components from science, social, and cultural points-of-view to these curricula. It is important that learners can connect the science contents to their real life (Wolterm et al., 2013). Interdisciplinary STEM can contribute by adding the relevant aspects and implementing active learning. All these increase the students' curiosity and their motivation to study new contents and develop capabilities they will need throughout their lives. Learning processes that include authenticity, teamwork, PBL, and solving of ill-defined problems will encourage choice of those STEM subjects in schools, and the graduates could continue in these subjects in Higher Education (HE) and take part in the industrial and academic sectors. While researching STEM literacies Tang & Williams (2019) emphasize the STEM literacies integration of skills and methods required in all STEM disciplines. They also point out that there is sufficient research evidence to differentiate among the relevant S.T.E.M literacies.

M.Ed. IN INTEGRATIVE STEM EDUCATION

The program was developed based on extensive literature research, educational policy documents, and consultation with experts. The development process constantly referred to disciplinary, methodological, educational, and pedagogical aspects.

Rationale

The M.Ed. program in integrative STEM education aspires to develop teachers and professionals from various areas to lead change in formal and informal education settings. The different fields of knowledge – science, technology, engineering, and mathematics – each have their own unique knowledge structure, methods, and principles, yet they share cross-disciplinary ideas, practices, and research methods. Understanding the unique as well as

common attributes enables a deeper understanding and ability to better apply the relevant knowledge and transfer principles and methods from one area of knowledge to another. The program emphasizes the development of skills that enable the processes of learning, research, and application of problem-solving methods in work teams comprised of students with diverse academic backgrounds, in which presentation and feedback processes take place as well, similar to the work required in the academic world and industry. Problem-solving processes are central to the program and will be expressed in all courses, especially in learning from existing projects in industry and the academic environment, in the development of scientific-technological projects, and in the development and implementation of projects for educational frameworks. The program will also raise social and ethical aspects that are intertwined in these fields of knowledge, including encouragement of integration of females and minorities.

Objectives

The program curriculum addresses four main objectives:

1. Enhancing knowledge and a better understanding of STEM fields both separately and interdisciplinary perspective. This includes acquisition of knowledge in the STEM subjects, and acquisition of advanced thinking skills such as problem solving, critical thinking, computational thinking, and identification of analogies.
2. Developing pedagogic-content knowledge (PCK). This includes developing personal knowledge and skills required to apply the PBL approach, and developing skills in guiding and assessing pupils in an experiential learning environment.
3. Developing leadership and management skills required to initiate, lead and manage integrative STEM education in Israeli schools. This includes actual experience in leading a STEM PBL project.
4. Advancing the "teacher as researcher" approach. This includes developing the participants' perception of themselves as educational researchers applying action research as an infrastructure for understanding and performing research in STEM teaching through PBL.

Organizing principles

Integrative and relevant: Integration among the disciplines is central to the curriculum. All courses are designed to emphasize how the disciplines that comprise STEM are complementary to each other and contribute to achieving valuable goals. The projects to be developed will be anchored in complex and authentic real-world problems, which require the study of scientific, technological, and engineering content and use the design process to develop the most appropriate solution.

Implementation of Project-Based Learning (PBL): About half of the program's teaching hours will be conducted via PBL methodology, which enables active learning in context. Interdisciplinary learning will take place through three pillars: in processes of analyzing real-world projects as case studies, in the development of projects within the program "incubator", and in educational frameworks.

Modeling teaching-learning methods: The learning methods implemented by program faculty to teach their courses will serve as a model for implementation in schools. Some key principles of the teaching methods are the role of the teacher as a facilitator/coach in an active learning

process, implementing long-term learning activities with emphasis on research, problem solving, critical thinking, and teamwork.

Evaluation of students: Evaluation processes are central. Students will be involved in constructing the evaluation tools. The focus of evaluation will be on learning processes conducted in teams, with emphasis on the process, including in relation to the expression of “soft skills”, and not only on the product. Both formative and summative, qualitative and quantitative assessment will be used.

Partnerships: The basis for successful implementation of the rationale and goals of the curriculum is the creation of partnerships with the academic world, industry, and formal and informal educational frameworks. Students will visit actual projects, experience work in real laboratories and workshops, and will be guided by researchers. Collaboration will contribute to producing products that are valuable and meaningful for society.

Integration of females: An important issue in STEM education is the limited number of girls that choose to specialize in STEM subjects. This gap is expressed in high schools, and has increased significantly in the academic world and in industry. Hence, one of the program's educational targets is to equip students with different teaching methods that will enable them to build girls' confidence, curiosity, and motivation to excel in STEM fields.

Program description

The M.Ed. program extends two years and has two study tracks: a thesis and a non-thesis track (38 and 42 academic credit hours, respectively). The program consists of compulsory courses (22 credits), two seminars (8 credits), elective courses (4 credits), and a final project (8 credits) to be implemented in educational settings. The program includes interdisciplinary courses such 'Biomimicry' and 'Biosphere Research', and education and pedagogy courses, such as 'Education for Values in Science and Technology' and 'Computational Thinking'. The two intended research seminars are: 'Reforms and Changes in Scientific and Technological Education and their Implications for Teaching and Learning', which is based on theoretical research methodologies; and 'Action Research in Relation to a STEM Project Implementation', which involves methods of action and self-research on a case study conducted in the program.

Three core courses will be conducted in the PBL method: (1) 'Investigating Authentic Projects from the Academic World and Industry', which adopts the reverse engineering approach to analyze areas of knowledge and methodologies used in the design and development of the project; (2) 'Developing an Integrative STEM Project' that aims to solve a real problem and develop a product (based on all the organizing principles); (3) 'Developing an integrative STEM Education Project' to be implemented in an educational framework, and investigate/research this implementation.

Summary

The M.Ed. program of Integrative STEM Education is unique in Israeli HE, in its concept and methods of integrating among all STEM subjects, in its stated organizing principles, and in the extent of use of PBL.

Significant challenges are identified in the development of the program and are anticipated in its implementation:

1. Curricular issues – proportion between disciplinary courses and interdisciplinary courses.
2. Creating partnership and collaboration – with important stakeholders for the success of the program: industrial companies, with formal and informal education frameworks, and with researchers in academia.

3. Faculty development – In order that the program itself models the competencies required of the graduates of the program, the program faculty needs to be competent in the various teaching methods on which the program is based: the PBL approach for solving interdisciplinary problems, and teaching collaboratively in teams using the same methods that their students will use. Additionally, the staff needs to be able to implement the design approach of thinking, its new role as a coach, and to teach with other faculty (team teaching).
4. Dealing with resistance – some teachers and schools preserve the disciplinary approach and structure, and have difficulty to change it into the interdisciplinary approach. The teacher students following this program may face objections in schools and need to be equipped with the tools to overcome such resistance and promote change.
5. Allocating students – the student body should be reasonably balanced in their core disciplines. Particularly, teams should include students from each STEM field, especially from the engineering field (that we lack in our college).

We are currently at the stage of faculty training as a necessary step prior to writing the course syllabi for the program. This stage is crucial in order for the syllabus to be coherent and to appropriately implement the program's content, concepts, and teaching methodologies. The program is to be launched in 2021.

REFERENCES

- Bybee, R. W. (2013). *The Case for STEM Education: Challenges and Opportunities*. Arlington, VA: NSTA press.
- Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 70(1), 30.
- Cagle, N. L., Caldwell, L., & Garcia, R. (2018). K-12 Diversity Pathway Programs in the E-STEM Fields: A Review of Existing Programs and Summary of Unmet Needs. *Journal of STEM Education*, 19(4), 12-18.
- Capraro, R. M., Capraro, M. M., & Morgan, J. R. (2013). *STEM Project-Based Learning. An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach*. Rotterdam, The Netherlands: Sense Publishers.
- Capraro, R. M., & Slough, S. W. (2013). Why PBL? Why STEM? Why Now? In R.M Capraro, M. M. Capraro, & J. R. Morgan (Eds.), *STEM Project-Based Learning. An Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach* (pp. 1-5). Rotterdam, The Netherlands: Sense Publishers.
- Dugger, E. W. (2010). Evolution of stem in the United States. Paper presented at the 6th Biennial International Conference on Technology Education Research in Australia. Retrieved from: <http://www.iteea.org/Resources/PressRoom/AustraliaPaper.pdf>
- Figliano, F. J. (2007). Strategies for Integrating STEM Content: A Pilot Case Study. VTechWorks. Virginia Tech. Retrieved from: <https://vtechworks.lib.vt.edu/handle/10919/36083>
- Fulton, K., & Britton, T. (2011). *STEM Teachers in Professional Learning Communities: From Good Teachers to Great Teaching*. Washington, DC: National Commission on Teaching and America's Future.
- Hanover Research. (2011). K-12 STEM education overview, Washington, DC: Hanover Research. Retrieved from: <http://www.hanoverresearch.com/wp-content/uploads/2011/12/K-12-STEM-Education-Overview-Membership.pdf>
- Howarth, S., & Scott, L. (2014). *Success with STEM*. New York: Routledge.
- Joyce, A., & Dzoga, M. (Eds.) (2013). Science, technology, engineering and mathematics education, Overcoming challenges in Europe. Retrieved from: https://workshop.intel.com/STEMacademy/download/04-2011-Intel-Educator-Academy-EMEA-white_paper.pdf

- Klaassen, R. G. (2018). Interdisciplinary education: a case study. *European Journal of Engineering Education*, 43(6), 842-859.
- Lynch, S. (2012). The new wave of STEM-focused schools. Free webinar. Retrieved from: <http://www.doe.in.gov/sites/default/files/ccr/inclusive-stem-high-schools.pdf>
- Mayes, R., Rittschof, K., Gallant, B., & Marti, C. (2017). Real STEM: An Interdisciplinary STEM Program. *Journal of Research in STEM Education*, 3(1/2), 1-16.
- Milner-Bolotin, M. (2018). Evidence-Based Research in STEM Teacher Education: From Theory to Practice. *Frontiers in Education*, 3, paper 92, 1-9.
- Reinholz, D., Slominski, T., French, T. A., Pazicni, S., Rasmussen, C., & McCoy, B. (2018). Good Problems within and Across Disciplines. *Journal of Research in STEM Education*, 4(1), 37-53.
- Sanders, M., & Wells, J. G. (2006). Integrative STEM education. Retrieved from: <http://www.soe.vt.edu/istemed/>
- Tseng, K. H., Chang, C. C., Lou, S. J., and Chen, W. P. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education*, 23, 87-102.
- Tang, K. S., & Williams, P. J. (2019). STEM literacy or literacies? Examining the empirical basis of these constructs. *Review of Education*, First published: 26 December 2018. <https://doi.org/10.1002/rev3.3162>
- Wolterm B. H. K., Lundeberg, M. A., & Bergland, M. (2013). What makes science relevant? Students perceptions of multimedia case learning in ecology and health. *Journal of STEM Education*, 14(1), 26-33.
- Zollman, A. (2012). Learning for STEM Literacy: STEM Literacy for Learning. *School, Science and Mathematics*, 112(1), 12-19.

Scale Development for Measuring iDesign Content Connections in Pre-Service STEM Teachers.

Elizabeth Deuermeyer, Michael A. de Miranda



Elizabeth Deuermeyer
Texas A&M University
USA
e.deuermeyer@tamu.edu



Michael A. de Miranda
Texas A&M University
USA
demiranda@tamu.edu

ABSTRACT

The development of valid and reliable scales to measure student integrated design (iDesign) content and knowledge fusion is a challenge that must be overcome by the STEM education community. This manuscript reports on the efforts of a team of university engineering education and test and measurement faculty cooperating with a pre-service teacher methods course involving science, mathematics, and engineering and technology teachers to measure the effects of student participation in an interdisciplinary long-term engineering design problem on iDesign content knowledge and application. In the context of this scale development study, science, mathematics, and engineering and technology pre-service teachers learned to co-plan a trans-disciplinary engineering design unit and challenge that would engage teams of science, mathematics and engineering and technology students to design, test, analyze and construct solutions to design problems that emphasized the integration of these core subjects in a iDesign environment. This proof-of-concept study examined the challenges of building a scale to measure pre-service teachers iDesign capabilities in creating design-based problems.

Keywords: integrated design education; field study; scale development; engineering design

Introduction and Background

The current national emphasis in the USA on STEM education has prompted researchers and practitioners in these fields to focus on three critical areas: (a) review of our current mathematics, science, and engineering curricula; (b) our pedagogical practices and utilization of existing and emerging technology; and (c) our ability to design, integrate, and assess exemplary learning environments (National Research Council [NRC], 2012). As asserted in a recent report, engineering design projects can serve as a catalyst for integrating learning across STEM disciplines (Katehi, Pearson, & Feder, 2009). Thus, one of the primary goals of the current study was to use an engineering design task to increase pre-service teachers' perceptions of the interrelated nature of integrated design (iDesign) content knowledge (Brown, 1992). However, a critical precursor to testing the cross-curricular iDesign intervention effects was the ability to measure perceptions of co-dependent iDesign content knowledge

reliably. Therefore, this brief report focuses on an initial scale development and the results of an intervention designed to change pre-service student perceptions of the co-dependent nature of iDesign content.

The recent release of the Next Generation Science Standards (NGSS) in the US marks a significant shift in the core concepts and approaches guiding science, technology, engineering, and mathematics education content in the coming years (NGSS, 2013). Most notable is the inclusion of engineering and technology concepts in a framework that emphasizes practices, crosscutting concepts, and core ideas. The repositioning of engineering and technology content within science education brings to light new opportunities and challenges when conceptualizing the design and delivery of instruction in STEM subjects, especially when examining the role of design in pre-service teacher preparation. Moreover, realizing the full potential of the NGSS will require new conceptions of learning and instruction being adopted to include the richness of unifying practice, inquiry, and design across STEM concepts and contexts.

The NGSS articulates a broad set of expectations for students in science grounded in practices and inquiry. Within these guiding standards are three major dimensions around which grades K-12 science education needs to be integrated into standards, curriculum, instruction, and assessment. These dimensions include: scientific and engineering practices; crosscutting concepts that unify the study of science and engineering through their common application across fields; and core ideas in four disciplinary areas: physical sciences, life sciences, earth and space sciences, and engineering, technology, and applications of science (NGSS, 2013).

Integrating the three dimensions of scientific and engineering practice, crosscutting concepts, and disciplinary core ideas that cover traditional scientific fields of study (i.e. physical science, life science, and earth and space science) now includes the addition of engineering, technology, and applications of science. Integrating the three dimensions could prove elusive, however approaches informed by research on teaching and learning from cognitive sciences combined with aggressive methodological approaches to measuring student learning within the three dimensions can yield promising results.

Problem of Measurement

The current study sought to develop an instrument that would be sensitive to changes in pre-service students design thinking as a result of participation in the idesign intervention. An example of the challenges and progress that help inform this pilot study are informed from well-established STEM education fields. Interdisciplinary integration of math curriculum within other content areas has been a focus of investigation for numerous content areas, such as science and the humanities (Angel & LaLonde, 1998; Elliott, Oty, & Korey, 2002). Therefore, the authors identified a measurement instrument similar to the goals of this study.

Math Across the Curriculum (MATC) is a teaching model developed to integrate mathematics content across humanities courses (Korey, 2000, 2002). The MATC program created nine courses linking mathematics content with humanities disciplines. Researchers developed a multi-assessment instrument to measure the impact of the MATC program on student perceptions and beliefs and provided initial validity evidence for the instrument (Korey, 2000). In the current study, researchers adapted items tapping the perceptions of the interrelated nature of design to STEM contents. The process for adaption involved defining the target constructs (i.e., *capability to effect change*, *ability to understand inventory*, *ability to manipulate ideas*, and *ability to imagine future realities*) and matching items to the facets of the underlying constructs. For this project a post-doctoral research scientist and a faculty member served as the context experts that reviewed the survey instructions and item content for clarity, non-redundancy, and relevance to the underlying constructs (Haynes, Richard, & Kubany, 1995; Netermeyer, Bearden, & Sharma, 2003). Therefore, the adapted scale items were designed

to assess student perceptions of the interrelated nature of designerly constructs across the STEM fields.

Having adapted an instrument to the needs of the complex classroom intervention, the specific goals of the current study were to (a) assess the initial evidence of the reliability and validity for the iDesign instrument and (b) to investigate the effect of the intervention on pre-service teachers design thinking change. We hypothesized that the measurement model for the instrument would exhibit a simple structure (i.e., a single factor). Furthermore, we hypothesized that students would perceive higher levels of connections between the STEM disciplines and designerly thinking after participating in the iDesign intervention.

Method

This paper reports on the first stage in the development of a questionnaire to measure the perceived designerly thinking capabilities of pre-service teachers, and is a smaller part of a larger study in which the authors are investigating methods of shifting teacher education to STEM teacher education with an emphasis on engineering and technology.

Intervention

Subject areas are often isolated from each other in teacher preparation programs, similar to a high school student's experience: you have one class on math methods, another on science, and another in reading, and so on. For this study, the condition was changed so that the math and science methods courses operated as one, changing from two separate Math and Science methods courses into one cohesive Engineering methods course. Prior to the start of the semester, students in the intervention class took the survey instrument along with several other survey questions related to the larger project. The introduction to engineering methods took place over 4 weeks, as the course only meets once a week. The first session involved students listening to a one-hour lecture on engineering and the engineering design process. The second session consisted of 2 hours of team building activities designed to highlight several objectives: 1) to understand the importance of working together to pay close attention to team tasks; 2) to identify key elements of successful team performance; and 3) to develop excellent teamwork skills and break down barriers between students. During the third session, students were taken through a design thinking workshop with a well-known international scholar on designerly thinking and learning. Finally, students were given the instruction for their final project during the last session. This Design Team Problem Project that would be a major grade for the course. The instructors used one 60-minute session to discuss the different artifacts of the project, which included:

- **Design Blueprint** with an accompanying student quiz that listed broad and specific concepts, operationalizations, level of Bloom's Taxonomy, connection to team member concepts, and the item number on the quiz that mapped to that concept. There was a section to list both the math and science concepts being explored.
- **Design Brief** which described the context, task, and design criteria for the project.
- **Problem Poster** showcasing a brief visual representation of the design problem.
- **Solutions poster** which presented a solution to the design problem.

This project required the use of both math and science related content. Students formed groups of four in which they would be working as a team. The project required the students to develop an engineering design-based problem for students in a classroom that incorporated both math and science curriculum standards appropriate for the grade-level they chose to work under. After developing the problem, the teams attempted to actually solve the problem

as their students would, and the project culminated with presentation that reported both the teacher artifacts and the student-created artifacts for the problem.

Measurement

Our goal was to create an instrument to measure specific target constructs reflecting designerly thinking: *capability to effect change or improvements; ability to understand and take inventory of what one has or has not experienced; ability to take ideas and manipulate in the mind or with others; and the ability to imagine aspects of design in order to envision a future reality*. An original questionnaire was developed and administered, and factor-analyzed. In creating items for the original questionnaire, an attempt was made to be as inclusive as possible. Items were gathered from a detailed examination of designerly thinking literature (i.e. Stables, 2008; Stables & Kimbell, 2007; Johansson-Skoldberg, Woodilla, & Cetinkaya, 2013). In addition to reviewing the literature, the authors had the opportunity to discuss the construct items in person with a well-known design thinking scholar during a campus visit (R.Kimbell, personal communication, February 5, 2019). The result was twenty-nine items which were roughly classified into four different characteristics reflecting the target constructs.

The designerly thinking questionnaire was part of a larger survey that was administered to the students at the beginning of the academic semester. The questionnaire received by subjects contained each of the 21 items listed separately followed by a response measure consisting of a five-point scale with one being “really disagree” and five being “really agree”. The survey also asked questions to measure students’ prior knowledge or experience and comfort levels with concepts such as design thinking, making and maker spaces, the engineering design process, and co-planning activities with other STEM teachers. The questionnaire can be found in Appendix A.

Subjects

The questionnaire was administered to 29 science and mathematics pre-service teachers at an institution in a southern state of the United States located in an urbanized area with several smaller rural towns located within a 30-45 minute drive of the university. Twenty-eight of the subjects were female. Twenty of the students identified as White, seven as Hispanic, and two as African American. The department in which these participants reside offers a Bachelor of Science in Interdisciplinary Studies with certification in EC-6 or middle grades with either a math/science or Language Arts/Social Studies specialization. In addition to course-work, the students spend extensive time in the middle school classroom as part of their field-based experience.

Data Analysis

Prior to running the analysis, the items were evaluated by the authors to ensure that the items fully covered the constructs we were interested in exploring and were clear of mistakes and confusing language. A factor analysis was performed using a principle-component factor analysis with vari-max rotation. An item was considered to load significantly on a factor if it had a primary loading of .30 or above. Four factors were requested based on the fact that the items were designed to index four concepts: *capability to effect change, ability to understand inventory, ability to manipulate ideas, and ability to imagine future realities*.

Results

Exploratory principal axis factor analysis with varimax rotation was conducted to assess the underlying structure for the 21 items of the Designerly Thinking Inventory (the assumption of independent sampling was met. The assumptions of normality, linear relationships between pairs of variables, and variables’ being correlated at a moderate level were checked). We requested for SPSS to extract based on an Eigenvalue greater than 2, which resulted in 3 factors. After rotation, the first factor accounted for 14.1%% of the variance, the second factor accounted for 11.3%, and the third factor accounted for 11. Table 4 displays the items and factor loadings for the rotated factors, with loadings of less than |.3| omitted to improve clarity.

Table 1. Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Var1	4.43	.504	28
Var2	4.64	.678	28
Var3	4.50	.577	28
Var4	3.86	1.079	28
Var5	2.79	1.067	28
Var6	4.36	.780	28
Var7	4.07	.900	28
Var8	2.50	1.139	28
Var9	4.54	.576	28
Var10	4.86	.356	28
Var11	4.57	.573	28
Var12	4.43	.634	28
Var13	3.25	1.323	28
Var14	2.82	1.307	28
Var15	3.39	.956	28
Var16	4.36	.621	28
Var17	4.21	.568	28
Var18	3.79	.876	28
Var19	3.89	.737	28
Var20	4.82	.476	28
Var21	4.54	.576	28

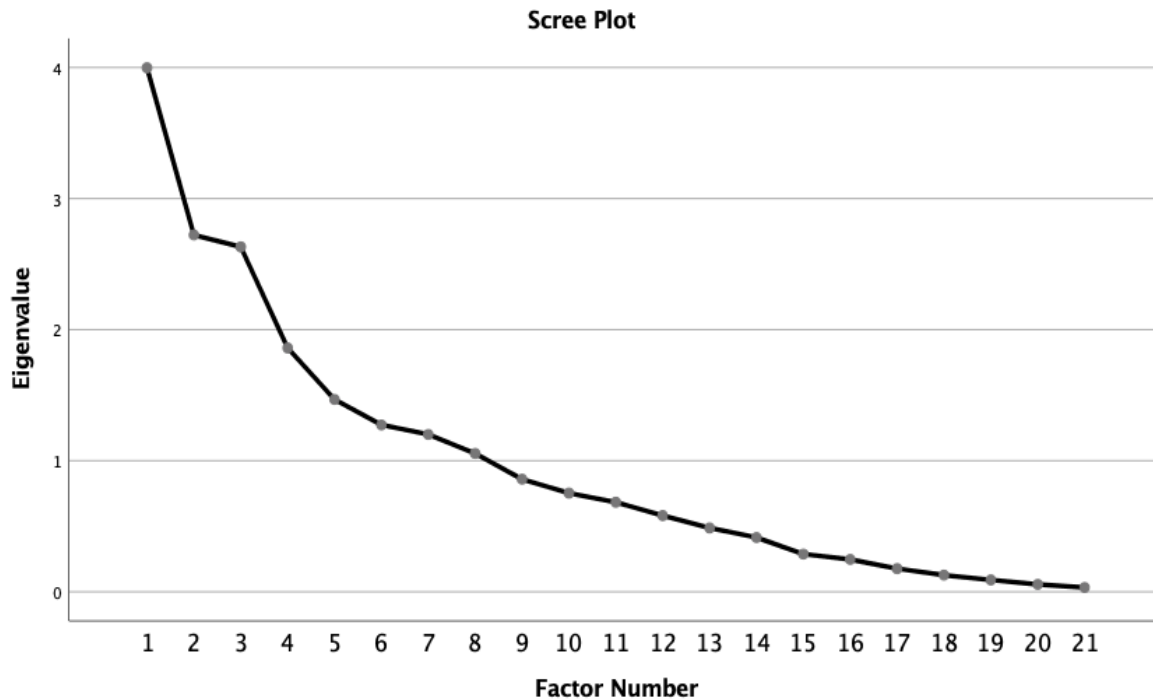
Table 1 includes descriptive statistics for each variable. One assumption is that the determinant should not be zero. If the determinant is zero, then a factor analytic solution would not be found, as this would require dividing by zero, which would mean that at least one of the items can be understood as a linear combination of some set of other items. This was not the case here.

Table 2 represents the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy tells us whether or not enough items are predicted by each factor. Since our number is below .5 (KMO value= .361), we know that there were not sufficient items for each factor. However, the Bartlett test is significant ($p < .05$) which means that the variables are correlated highly enough to provide a reasonable basis for factor analysis.

Table 2. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.361
Bartlett's Test of Sphericity	Approx. Chi-Square	254.409
	df	210
	Sig.	.020

Figure 1. Scree Plot



A scree plot (Figure 1) shows the eigenvalues on the y-axis and the number of factors on the x-axis. It always displays a downward curve. The point where the slope of the curve is clearly leveling off (the “elbow”) indicates the number of factors that should be generated by the analysis. For our analysis we can see that there are 4 factors that were pulled.

Table 4 shows the Rotated Factor Matrix of factor loadings. Rotation makes it so that, as much as possible, different items are explained or predicted by different underlying factors, and each factor explains more than one item. Note that in Table 4 the items are sorted into four somewhat overlapping groups of items. The items are sorted so that the items that have the highest loading from factor 1 are listed first, and they are sorted from the one with the highest factor weight or loading to the one with the lowest loading from the that first factor. We requested that loadings with less than $|.3|$ be excluded from the output.

Table 4. Rotated Factor Matrix^a

	Factor		
	1	2	3
Var3	.766		
Var24	.597		
Var17	.584		
Var10	.486		
Var23	.472		
Var5	.454		
Var4	.415		
Var27		.836	
Var15		.602	
Var8		.564	
Var21		.513	

Var14		.456	
Var28			
Var20			.741
Var19			.552
Var22			.528
Var18	.458		.501
Var1			.446
Var7			.411
Var12			
Var16			

Extraction Method: Principal Axis Factoring.

Rotation Method: Varimax with Kaiser Normalization.^a

a. Rotation converged in 9 iterations.

The Total Variance Explained (Table 5) shows how the variance is divided among the 4 possible factors. We can see here that 43.5% of the total variance can be explained by the first four factors.

Table 5.

Total Variance Explained

Factor	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	2.961	14.098	14.098
2	2.389	11.377	25.475
3	2.306	10.979	36.453

To assess whether the data from the variables in each factor form three reliable scales, Cronbach's alphas were computed.

Table 6. Factor 1

Reliability Statistics

Cronbach's Alpha	Cronbach's Based on Standardized Items	Alpha on N of Items
.700	.730	7

Inter-Item Correlation Matrix

	Var3	Var24	Var17	Var10	Var23	Var5
Var3	1.000	.439	.369	.468	.303	.383
Var24	.439	1.000	.260	.235	.422	.353
Var17	.369	.260	1.000	.399	.372	.201
Var10	.468	.235	.399	1.000	.161	-.065
Var23	.303	.422	.372	.161	1.000	.123
Var5	.383	.353	.201	-.065	.123	1.000

Var4	.378	.218	.303	.214	.073	.238
------	------	------	------	------	------	------

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Total Correlation	Item-Squared Correlation	Multiple Correlation	Cronbach's Alpha if Item Deleted
Var3	24.54	8.184	.656	.471		.611
Var24	25.29	8.360	.536	.335		.635
Var17	24.75	8.861	.510	.321		.648
Var10	25.11	8.692	.318	.370		.693
Var23	25.39	8.544	.367	.279		.678
Var5	25.32	8.226	.291	.300		.716
Var4	24.68	9.560	.363	.195		.679

**Table 7. Factor 2
Factor 2 Reliability Statistics**

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.671	.724	5

Factor 2 Inter-Item Correlation Matrix

	Var27	Var21	Var15	Var8	Var14
Var27	1.000	.349	.500	.478	.362
Var21	.349	1.000	.406	.186	.273
Var15	.500	.406	1.000	.190	.567
Var8	.478	.186	.190	1.000	.135
Var14	.362	.273	.567	.135	1.000

Factor 2 Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Total Correlation	Item-Squared Correlation	Multiple Correlation	Cronbach's Alpha if Item Deleted
Var27	18.11	2.470	.621	.420		.548
Var21	18.57	2.476	.390	.196		.637
Var15	18.07	2.810	.576	.455		.596
Var8	18.57	2.254	.325	.233		.700
Var14	18.39	2.544	.407	.331		.627

Table 8. Factor 3

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.644	.685	6

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Total Correlation	Item-Multiple Correlation Squared	Cronbach's Alpha if Item Deleted
CapEffChgImpactVar1	16.46	11.665	.354	.227	.625
CapabilityECIVar7	18.11	9.507	.379	.216	.599
ManipulateDDMVar18	17.64	8.460	.380	.225	.609
ManipulateDDMVar19	18.07	8.143	.441	.364	.578
ManipulateDDMVar22	16.68	11.041	.469	.253	.598
ManipulateDDMVar20	17.50	9.815	.402	.323	.591

Inter-Item Correlation Matrix

	Var1	Var7	Var18	Var19	Var22	Var20
Var1	1.000	.315	.278	.064	.314	.253
Var7	.315	1.000	.354	.158	.323	.158
Var18	.278	.354	1.000	.284	.222	.095
Var19	.064	.158	.284	1.000	.353	.503
Var22	.314	.323	.222	.353	1.000	.317
Var20	.253	.158	.095	.503	.317	1.000

Tables 6, 7 and 8 report the Reliability statistics for the three rotated factors. Factor 1 had a high Cronbach's Alpha of .700 while Factors 2 and 3 were still high, but just under .700. This may be due to each factor only having a handful of items. None of the variables were above .90, which would mean some of the variables were repetitious. The Item-Total Statistics chart for each factor tells us that the items in each factor are somewhat correlated with the other items, although some of the items fall below .400, meaning some of the variables do not fit with that factor well, at least psychometrically.

Discussion

This paper reports on a first attempt to design a questionnaire that measures the perceived designerly thinking capabilities in pre-service teachers. We designed our items around four factors the authors felt were critical in designerly thinking: *capability to effect change*, *ability to understand inventory*, *ability to manipulate ideas*, and *ability to imagine future realities*. The three factors found in the analysis accounted for 36% of the total variance explained. However, based on our Kaiser-Meyer-Olkin (MKO) Test for Sampling Adequacy, we know that we need to refine and administer this questionnaire to a larger number of pre-service teachers before we can adequately assess whether our questions are valid in measuring designerly thinking. This will mean the authors will need wait until the fall semester when another group enrolls in the Senior Methods semester, giving additional time to refine questions. Refinement may be necessary as some items loaded in factors that we had not intended them to load. Multiple items in the questionnaire loaded fairly high in other factors, giving cause for the authors to consider wording of items so that it is truly measure one factor instead of multiple. Additionally, a reliability statistics test revealed that some questions do not correlate well with some of the variables, at least psychometrically. The authors will need to refine, revise, and possibly even throw out some of the questions on the assessment when preparing to administer the assessment again.

References

- Angel, S. and LaLonde, D. (1998). Science success strategies: An interdisciplinary course for improving science and mathematics education. *Journal of Chemical Education*, 75, 1437-1441.
- Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences*, 2, 141-178.
- Elliott, B., Oty, K., McArthur, J., and Clark, B. (2001). The effect of an interdisciplinary algebra/science course on students. *International Journal of Mathematical Education in Science and Technology*, 32, 811-816.
- Haynes, S. N., Richard, D. C. S., & Kubany, E. S. (1995). Content validity in psychological assessment: A functional approach to concepts and methods. *Psychological Assessment*, 7, 238-247.
- Johansson-Sköldberg, U., Woodilla, J., & Çetinkaya, M. (2013). Design thinking: past, present and possible futures. *Creativity and innovation management*, 22(2), 121-146.
- Katehi, L., Pearson, G., & Feder, M. (Eds.) (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Committee on K-12 Engineering Education. Washington, DC.
- Kimbell, R., & Stables, K. (2007). *Researching design learning: Issues and findings from two decades of research and development* (Vol. 34). Springer Science & Business Media.
- Korey, J. (2002). Successful interdisciplinary teaching: Making one plus one equal one. 2nd International Conference on the Teaching of Mathematics at the Undergraduate Level Hersonissos, Crete, July 1-6, 2002, retrieved on 3/9/2012, from <http://www.math.uoc.gr/~ictm2/Proceedings/pap123.pdf>

Korey, J. (2000). Dartmouth college mathematics across the curriculum evaluation summary: Mathematics and humanities courses. retrieved on 3/9/2012, from <http://www.math.dartmouth.edu/~matc/Evaluation/humeval.pdf>

Netemeyer, R. G., Bearden, W. O., & Sharma, S. (2003). Scaling procedures: Issues and applications. Thousand Oaks, CA: Sage Publications.

NGSS Lead States (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

The National Research Council, (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Committee on a Conceptual framework for New Science Education Standards. Board on Science Education, Division of Behavioral and Social Science Education. Washington, DC: The National Academies Press.

Stables, K. (2008). Designing matters; designing minds: The importance of nurturing the designerly in young people. *Design and Technology Education: An International Journal*, 13(3)

Appendix A

Designerly Thinking Questionnaire Items

V1. When faced with a problem, I know I can use my skills and knowledge to create change.
V2. I believe it is important to make improvements in the world.
V3. I believe that change can be a good thing.
V4. I believe I have the resources available to effect change or improvement in my world.
V5. I feel comfortable in situations where there is no fixed field of knowledge to draw on.
V6. When faced with a task, it is important to recognize what I do not know about a problem.
V7. When trying to solve a problem, it is important to talk with all the stakeholders.
V8. In most problems, I can quickly decide what the solution is without doing research.
V9. I believe it is important to consider all possible solutions even if I think I already know the answer to the problem.
V10. I believe there are many acceptable ways to model possible solutions.
V11. I see the value in being able to model the future via various mediums, such as written or verbal communication, mathematical models, or through material or computer modeling.
V12. I have skills that can be used to model possible solutions, such as being able to discuss my ideas with others, writing, calculating, drawing, or Making.
V13. I can sketch the future or a solution to a problem, like on a napkin at dinner.
V14. I can build prototypes and test them.
V15. I can express a proposed structure using mathematical models.
V16. I can break down problems into small parts to better understand the context.
V17. Once I have an idea, I can develop ways of verifying that my idea may work.
V18. When thinking about my design as a solution, I consider its appearance, function, marketability, economic viability, or wider social psychological impact.
V19. I can discuss my ideas of the future with peers in a casual conversation, or in a formal presentation as if I were trying to persuade a client.
V20. Discussing the problem as a group can help to enhance the shared understanding of the task we are trying to complete.
V21. When choosing a final solution for a problem, I believe it is important for the group to come to an agreement on the solution.

Curriculum Development in Technology Teacher Education: Integrating Epistemology, Pedagogy and Capability.

Ronan Dunbar, Jeffrey Buckley, Niall Seery



Rónán Dunbar
Athlone Institute of
Technology, Ireland
rdunbar@ait.ie



Jeffrey Buckley
Athlone Institute of
Technology, Ireland
KTH Royal Institute of
Technology, Sweden
jbuckley@ait.ie



Niall Seery
Athlone Institute of
Technology, Ireland
nseery@ait.ie

ABSTRACT

Technology Education continues to establish itself internationally as a primary contributor to a broad and balanced curriculum that prepares students for the technological age that we are living in. It is critical that those responsible for the shaping and delivery of our subjects pay special attention to how they are conceived and delivered to students engaging in the associated subjects. A critical influencer in how technology subjects manifest themselves within the classrooms of our schools is the effectiveness of the teacher education obtained by those who choose to teach them.

This paper outlines a research informed integrated model of concurrent Technology Teacher Education curriculum design and offers insights into the design and delivery of Technology Teacher Education. The framework is presented from a learning perspective in an Irish context, focusing on catering for the contemporary values and competences outlined in national curricula. The paper provides valuable insights into the evolution of contemporary pre-service Technology Teacher education paradigms.

The paper concludes by offering a strategic alignment of content and context through a generative learning model to nurture the attitudes, skills and knowledge that act as the foundational building blocks of an effective, informed, innovative, reflective teacher of technology education.

Keywords: Initial Technology Teacher Education, Integrated Curriculum Design

Introduction

The successful enhancement and development of Technology Education in the future depends on continued research endeavours and subsequent discussions amongst the international community of technology education researchers and educators. From these joined-up efforts must come the integration of the findings of such research into the teaching and practices of technology education in our schools and classrooms. In this paper, the authors aim to consolidate and contextualise selected elements of education research outcomes to inform curriculum design for initial technology teacher education (ITTE). A critical aspect of ITTE curriculum development is the consideration of perspectives of student teachers as they navigate the dimensions of their teacher education. This is even more relevant when we consider these student teachers as the facilitators of future agendas within the subject area.

In an Irish context, it is timely to consider such curriculum development as the National Council for Curriculum and Assessment (NCCA) finalises the review of the four technology subjects being offered at lower second level. The new suite of subject syllabi being implemented for the first time in September 2019 will require a redefined conception of the contemporary goals outlined in the subject documentation. It is critical to ensure that these goals meaningfully materialise and are not merely addressed through surface level change of practices associated with the previous out-going syllabi. An apparent place to address this required change of pedagogical practices and attitudes is through the education of future technology teachers. This paper focuses on informing technology teacher education, maximising impact through the articulation of research contributions into the core structures of curriculum design.

Initial Teacher Education

Powerful teaching is increasingly important in contemporary society. Education is paramount to the success of both individuals and nations, and growing evidence demonstrates that (Darling-Hammond, 2006). This is highlighted in a European context where Buchberger et al. (2000) state that:

“Teacher education across the European Union is a mass enterprise; more than half a million teacher students receive initial teacher education in more than one thousand institutions dealing with teacher education where more than fifty thousand staff (e.g. teacher educators, specialists in academic disciplines) and a large number of co-operating teachers (mentors) work. In-service education as well as further education have to be provided for more than four million teachers.”

Alongside the scale of the demand for teacher education, is the fact that it is also a complex area of study, both for undergraduate student teachers and faculty of educational institutions. If students of teaching are to genuinely “see into teaching”, then they require access to the thoughts and actions that shape such practice; they need to be able to see and hear the pedagogical reasoning that underpins the teaching that they are experiencing (Loughran, 2007). Edwards et al. (2002) stated that something happens to pre-service teachers during their professional development courses. She outlines that the obvious question to be answered is; “what is it that they (student teachers) have experienced on their courses that allows them to graduate successfully? What is the unique knowledge-base that higher education offers to student teachers on their teacher education courses?”

Preservice teachers should be encouraged to be metacognitive and become more aware of *how* they learn in teacher education courses with the intention of informing their decision-making as they construct their personal pedagogies. (Baird and Northfield, 1992, Hoban, 2002) Northfield and Gunstone (1997) described in their set of principles for teacher education how the student-teacher has needs and prior experiences which must be considered in planning and implementing the teacher preparation program and the nature and intensity of these needs should shift throughout the programme. For students of teaching, their learning agenda includes learning about the specific content being taught, learning about learning, and learning about teaching (Loughran, 2007).

This paper acknowledges the breadth and complexities of teacher education, and specifically looks at the enhancement of technology teacher education with an emphasis on developing technological knowledge.

Philosophy of Technology Education – Technological Capability as Technological Knowledge

Technological knowledge is categorised by its normativity, collective acceptance, non-propositionality and context specificity which has an impact on associated teaching and learning (de Vries, 2016). Internationally, the acquisition of technological knowledge is described as the process for a student becoming technologically capable (Gibson, 2008), technologically literate (Dakers, 2006), or acquiring a technological perspective (Barlex, 2000). There is considerable overlap between these constructs, and different countries tend to emphasise one over the others. In Ireland, the goals of technology education syllabi are typically described under the terminology of technological capability (DES, 2007a, 2007b). This framing allows for a description of technological knowledge with more clarity, for example Buckley et al. (2018) illustrate how technological knowledge maps onto Gorman's (2002) typology of knowledge for technology transfer (Figure 3).

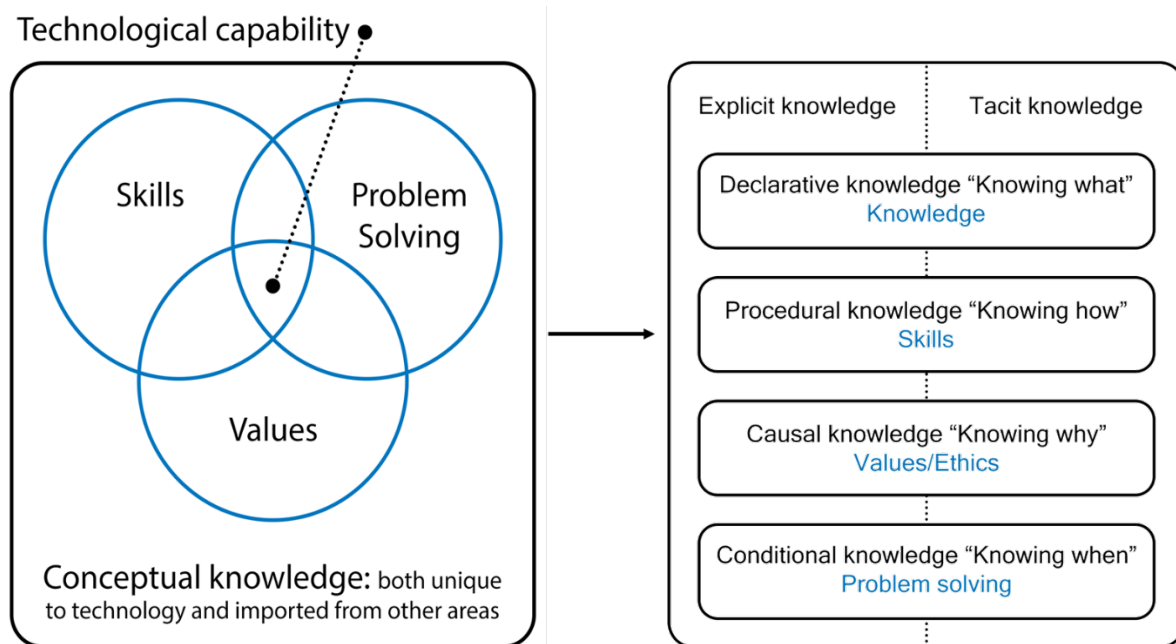


Figure 14. Technological capability as technological knowledge (Buckley et al., 2018).

Acknowledging the distinction between tacit and explicit knowledge (Collins, 2010; Polanyi, 1969), Buckley et al. (2018) describe the types of knowledge inherent to technology education as declarative leading to conceptual understanding, procedural, causal and conditional, and offer the following elaborations (pp.3-4):

- Declarative knowledge, synonymous with Ryle's (1949) knowing that and sometimes referred to as knowing what (Gorman, 2002), is the knowledge of terminology and facts (Huang & Yang, 2009).
- Conceptual knowledge is related to declarative knowledge (Gibson, 2008) in that it is associated with relationships between pieces of knowledge (McCormick, 1997).
- Procedural knowledge, synonymous with Ryle's (1949) knowing how, is knowledge about procedures, actions and steps (Pirttimaa, Husu, & Metsärinne, 2017) which Anderson (1983) notes is initially encoded as declarative knowledge before translating into procedural knowledge.

- Conditional knowledge (Alavi & Leidner, 2001), strategic knowledge (Gibson, 2008) or judgement (Gorman, 2002), also described as knowing when, relates knowledge of conditions and what to do in certain situations.
- Causal knowledge (Alavi & Leidner, 2001) or wisdom (Gorman, 2002), also described as knowing why, describes a knowledge of why certain actions should be taken both from a moral or ethical perspective and based on their causal effects.

This creates a clear understanding that students must acquire a certain body of declarative and procedural knowledge, which is culturally defined through post-primary syllabi, as well as through societal and technological advances, but that they must also learn to act within an ethical framework for the utilisation of such knowledge. To add further clarity in terms of the specific capability a technology student needs, Kimbell (2011, p. 7) describes how the declarative and procedural knowledge which is to be acquired is more akin to a “provisional knowledge” as it will be topic or task specific. Similarly, Williams (2009, pp. 248-249) argues that “the domain of knowledge as a separate entity is irrelevant; the relevance of knowledge is determined by its application to the technological issue at hand. So the skill does not lie in the recall and application of knowledge, but in the decisions about, and sourcing of what knowledge is relevant”, highlighting that it is knowledge search heuristics which should form the basis of what is considered technological knowledge and what should be an undercurrent for the development of learning objectives and pedagogical practices in technology education.

Research Informed Perspectives and Associated Theories of Learning

Role of Direct Instruction

Due to the nature of technological knowledge (Buckley et al., 2018), in particular the emphasis on knowledge heuristics (Williams, 2009), inquiry based approaches can appear intuitive. However, these approaches lack necessary empirical support in terms of learning (Kirschner, Sweller, & Clark, 2006; Sweller, Kirschner, & Clark, 2007). There can be an assumption that direct instruction does not involve posing problems or allowing students autonomy. This is not true, as such activities are considered critical for developing a strong conceptual understanding, provided sufficient foundational knowledge is taught first. Contemporary curricular design should allow students to experience an increased level of autonomy and a decrease in explicit guidance over time as they develop a foundational knowledge base and gain the required expertise to engage in self-direct learning. The initial stages of a programme should see students having the highest number of contact hours, where they will learn basic discipline, foundational and professional knowledge which they can build upon. It is essential at this stage, that students are highly supported and make relatively few decisions concerning their own learning. In contrast, in the later stages of their teacher education, there will be much greater autonomy in practice where learning will take place at an individual level and be heavily associated with individual student competencies and interests. The direction and application of knowledge can only happen as a result of the student defining the context for their learning. This is a defining feature of technology education.

As there is novel information presented throughout a programme of study, it is important that the novice-expert continuum (Kaufman, Baer, Cropley, Reiter-Palmon, & Sinnott, 2013) is appreciated. The direct instruction framework cannot be applied simplistically but must fluctuate to correlate to the introduction of novel information, which typically occurs at a topic/task level.

The programme architecture must be built to support this delivery and therefore it is essential to consider empirical research that will aid the student in contextual comprehension. Such programme architecture must support and deliver an integrated approach based on a generative paradigm of learning.

Generative Learning Theory

Generative learning takes place when the learner engages in appropriate cognitive processing during learning, including attending to the relevant information (i.e., selecting), mentally

organizing incoming information into a coherent cognitive structure (i.e., organising), and integrating the cognitive structures with each other and with relevant prior knowledge activated from long-term memory (i.e., integrating) (Fiorella, 2015). This approach to learning points technology education curriculum developers towards creating experiences that encourage students to initially consider the relevance of schema. From an ontological perspective, student teachers must be encouraged to consider what is relevant in today's global technological world, in our local cultures and communities and in the school settings that we live, teach and learn in. To coherently organise these "real" issues from an epistemological perspective requires student teachers to consider how these realities can inform what knowledge we should develop and how best to develop it. The integration of this knowledge is a methodological challenge, whereby suitable pedagogies for effective teaching and learning must be employed to ensure that acquired knowledge is aligned with prior experiences and values from within the learner's long-term memory. The application and emphasis of the generative learning theory can therefore lend itself to the development of a meta-cognitive technology teacher, with abilities to self-regulate their learning through selection, organisation and integration of schema. However, to develop the student technology teacher along a continuum from novice to expert requires the key skills associated with the discipline specific attribute of innovation, the underpinning research methods to enable meaningful inquiry and the associated reflective competencies of self-regulation and critique.

Technology Teacher as Researcher, Innovator and Reflective Practitioner

As Researcher

The concept of a teacher as a researcher has many interpretations. It has commonly been conceived that a teacher should conduct 'traditional' university research to inform theory (Flake, Kuhs, Donnelly, & Ebert, 1995) although there has been a shift towards conceptualising teachers as action researchers to reemphasise their primary role as educators (Laurillard, 2008). This conception of Technology Teacher Education is underpinned by the idea that teachers as researchers needs to strike a balance. Of foremost concern to the teacher should be the education of post-primary students. In achieving this, contemporary foundational and discipline specific educational research should be accessible to teachers in terms of practicality and the capacity for engagement. Importantly, a culture of research must be fostered in ITE programmes which facilitates this. Teachers should also contribute to research and theory where possible to progress educational practices. Teachers should be encouraged to take the role of research participants, action researchers, or independent researchers depending on their interests, motivations, and capacity for engagement. However, the real value in a teacher as a researcher is in teachers having the capacity to best support their students by being able to analyse their own classroom environments and employ what are considered best educational practices appropriately to address learners' needs. The concept of teachers as researchers should be considered critically and contextually to ensure students gain the skills to engage with relevant educational evidence, thus supporting their continued professional development post teacher education, and such that they can use research skills in their own future classrooms, i.e. by creating and interpreting educational assessments validly.

As Innovator

Considering the constructs of technological knowledge and technological capability as knowledge specific learning objectives, there is a need to consider the nature of the activity that technology education espouses. In this sense, the student is being considered more holistically and the question of what a technology student or a technologist is, must be asked. Technology teacher education curricula should be underpinned by the concept of technology teachers as innovators. In saying this, a distinction between creativity and innovation must be made to fully appreciate why the idea of innovators is so important. Both creativity and innovations have many verbal definitions. Sternberg and Lubart (1999, p. 3) define creativity as "the ability to produce work that is both novel (i.e., original, unexpected) and appropriate (i.e., useful, adaptive concerning task constraints)" while Van de Ven and Angle (1989, p. 12)

define innovation as “a process of developing and implementing a new idea”. Amabile (1996) differentiates them by describing creativity as the production of novel and useful ideas in any domain whereas innovation is the successful implementation of creative ideas within a domain. Further differentiations include the suggestion that creativity is about divergent thinking and innovation is about convergent thinking (Gurteen, 1998) and that creativity is the generation of novel and useful ideas while innovation is the process of bringing the best ideas to reality (Bisadi, Mozaffar, & Hosseini, 2012). Creativity underpins innovation, but the key characteristic of innovation and of technology students as innovators is that they make, craft, implement, or otherwise, to bring their creative ideas into reality in a purposeful way within a context.

This idea of technology teachers as innovators is reflected within the technology education literature, particularly in terms of the goal disposition of technology students and educators. Specifically, technology students should achieve a balance between being critical and speculative (Buckley & Seery, 2018; Buckley, Seery, & Canty, 2017; Seery, 2017). In this sense, being speculative is synonymous with being creative in the production of new ideas, whereas being critical emerges as technology students engage with the process of implementing their speculations in context. Indeed, being critical has been suggested as the signature pedagogy of technology education (von Mengersen, 2017) where being designerly is the primary activity (Stables, 2008). As such, in terms of the disposition and attitudes of technology education students, technology teacher education programmes should be conceived to promote a disposition of inquiry, requiring students to be speculative and critical, by engaging students in designerly activities. This approach and disposition afford potential for students to acquire technological knowledge and the pertinent associated knowledge search and evaluation heuristics, so they are enabled to go beyond observing the world as it is and envisaging the world as it could be.

As Reflective Practitioner

It is through the development of the previously two outlined professional attributes (researcher and innovator) that technology teachers can become capable reflective practitioners. Without an ability to conduct and/or integrate research into their pedagogical planning and delivery, technology teachers will lack a key competence in being able to reflect upon their teaching in relation to informed best practices. Likewise, if they do not personify innovative practice in their own teaching through creating innovative learning experiences and expose their pupils to engagement in innovative activities, then their ability to reflect on their fulfilment of the contemporary goals of technology education will be somewhat gauged against parameters that lack relevance.

Considering Curriculum Architecture

A suggested model of technology teacher education integrates specific content knowledge and foundational and professional educational studies, in line with the concurrent model, which is recommended as best practice for teacher education provision (Darling-Hammond, 2006). A suggested model is where the key areas of foundational studies, (i.e., curriculum studies, the history and policy of education, philosophy of education, psychology of education, and sociology of education) are all introduced in autumn semesters (i.e. initial semester of each year of study) and contextualised in education. In the subsequent spring semesters, each of these areas is considered again however the learning is contextualised in the area of technology education. This allows for an advanced treatment of the relevant knowledge, but through an approach that is tangible to the students learning holistically. Figure 2 illustrates how knowledge is acquired from a cognitive perspective. As illustrated, in autumn semesters the emphasis is placed on introducing new information and establishing the conceptual links within that information, whereas in spring semesters the emphasis is placed more on contextualising this information by providing additional knowledge to aid in assimilation and meaning making.

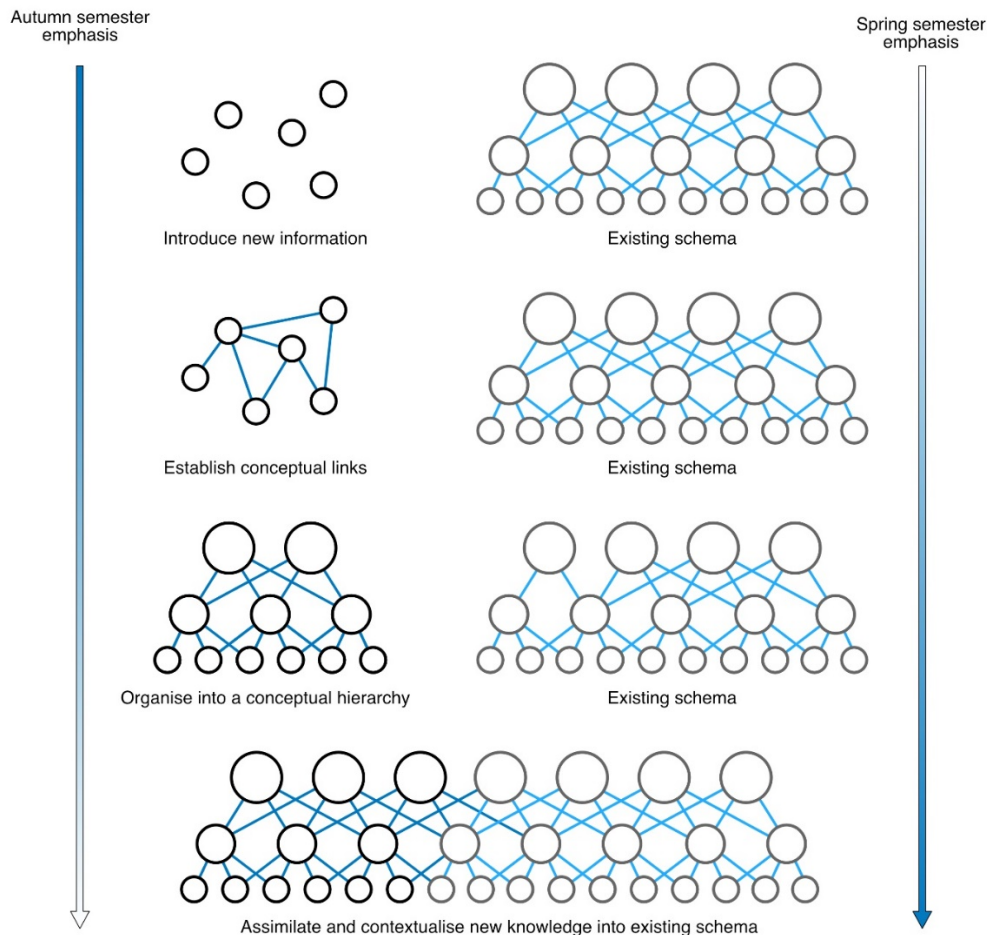


Figure 15 – Delivery and Contextualisation of New Knowledge

Conclusion

Due to a growing research knowledge base, Technology Education is now in a healthier position than it has ever been before. This paper has presented a conceptual framework for technology teacher education grounded upon general and technology education research, whereby an integrated, generative model of direct instruction is suggested to ensure the formation of critical perspectives amongst graduating technology teachers. Having a framework that is informed by empirical research allows us to demonstrate the effectiveness of teacher education provision and empower graduate technology teachers to enhance practices and exploit the full potential of technology education at post-primary level.

References

- Alavi, M., & Leidner, D. (2001). Review: Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS Quarterly*, 25(1), 107–136.
- Amabile, T. (1996). *Creativity and innovation in organizations*. Boston: Harvard Business Press.
- Anderson, J. (1983). *The architect of cognition*. Cambridge: Harvard University Press.
- Barlex, D. (2000). Resources for technology education in Scottish primary schools. *Journal of Design & Technology Education*, 5(1), 45–46.

- Bisadi, M., Mozaffar, F., & Hosseini, S. B. (2012). Future research centers: The place of creativity and innovation. *Procedia - Social and Behavioral Sciences*, 68(1), 232–243.
- Buckley, J., & Seery, N. (2018). Balancing curriculum intent with expected student responses to designerly tasks. *Design and Technology Education: An International Journal*, 23(1), 26–39.
- Buckley, J., Seery, N., & Canty, D. (2017). Heuristics and CAD modelling: An examination of student behaviour during problem solving episodes within CAD modelling activities. *International Journal of Technology and Design Education*. <https://doi.org/10.1007/s10798-017-9423-2>
- Buckley, J., Seery, N., Power, J., & Phelan, J. (2018). The importance of supporting technological knowledge in post-primary education: A cohort study. *Research in Science & Technological Education*. <https://doi.org/10.1080/02635143.2018.1463981>
- Collins, H. (2010). *Tacit and explicit knowledge*. Chicago and London: University of Chicago Press.
- Dakers, J. (Ed.). (2006). *Defining technological literacy: Towards an epistemological framework*. New York and Hampshire: Palgrave MacMillan.
- Darling-Hammond, L. (2006). Constructing 21st-Century Teacher Education. *Journal of Teacher Education*, 57(3), 300–314.
- de Vries, M. (2016). *Teaching about technology: An introduction to the philosophy of technology for non-philosophers*. Switzerland: Springer.
- DES. (2007a). *Leaving Certificate Design and Communication Graphics Syllabus*. Dublin: The Stationery Office.
- DES. (2007b). *Leaving Certificate Technology Syllabus*. Dublin: The Stationery Office.
- Flake, C., Kuhs, T., Donnelly, A., & Ebert, C. (1995). Reinventing the role of Teacher: Teacher as researcher. *The Phi Delta Kappan*, 76(5), 405–407.
- Gibson, K. (2008). Technology and technological knowledge: A challenge for school curricula. *Teachers and Teaching*, 14(1), 3–15.
- Gorman, M. (2002). Types of knowledge and their roles in technology transfer. *Journal of Technology Transfer*, 27(3), 219–231.
- Gurteen, D. (1998). Knowledge , creativity and innovation. *Journal of Knowledge Management*, 2(1), 5–13.
- Huang, S. L., & Yang, C. W. (2009). Designing a semantic bliki system to support different types of knowledge and adaptive learning. *Computers and Education*, 53(3), 701–712.
- Kaufman, J., Baer, J., Cropley, D., Reiter-Palmon, R., & Sinnott, S. (2013). Furious activity vs. understanding: How much expertise is needed to evaluate creative work? *Psychology of Aesthetics, Creativity, and the Arts*, 7(4), 332–340.
- Kimbell, R. (2011). Wrong ... but right enough. *Design and Technology Education: An International Journal*, 16(2), 6–7.
- Kirschner, P., Sweller, J., & Clark, R. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41(2), 75–86.
- Laurillard, D. (2008). The teacher as action researcher: Using technology to capture pedagogic form. *Studies in Higher Education*, 33(2), 139–154.

- McCormick, R. (1997). Conceptual and procedural knowledge. *International Journal of Technology and Design Education*, 7(1–2), 141–159.
- Pirttimaa, M., Husu, J., & Metsärinne, M. (2017). Uncovering procedural knowledge in craft, design, and technology education: A case of hands-on activities in electronics. *International Journal of Technology and Design Education*, 27(2), 215–231.
- Polanyi, M. (1969). *Knowing and being: Essays*. Chicago: Chicago University Press.
- Ryle, G. (1949). *The concept of the mind*. Chicago: University of Chicago Press.
- Seery, N. (2017). Modelling as a form of critique. In P. J. Williams & K. Stables (Eds.), *Critique in Design and Technology Education* (pp. 255–273). Singapore: Springer.
- Stables, K. (2008). Designing matters; Designing minds: The importance of nurturing the designerly in young people. *Design and Technology Education: An International Journal*, 13(3), 8–18.
- Sternberg, R., & Lubart, T. (1999). The concept of creativity: Prospects and paradigms. In R. Sternberg (Ed.), *Handbook of Creativity* (pp. 3–15). Cambridge, UK: Cambridge University Press.
- Sweller, J., Kirschner, P., & Clark, R. (2007). Why minimally guided teaching techniques do not work: A reply to commentaries. *Educational Psychologist*, 42(2), 115–121.
- Van de Ven, A., & Angle, H. (1989). An introduction to the Minnesota innovation research program. In A. Van de Ven, H. Angle, & M. Poole (Eds.), *Research on the Management of Innovation* (pp. 3–30). New York: Harper & Row.
- von Mengersen, B. (2017). Hyper design thinking: Critique, praxis and reflection. In P. J. Williams & K. Stables (Eds.), *Critique in Design and Technology Education* (pp. 301–320). Singapore: Springer Nature.
- Williams, P. J. (2009). Technological literacy: A multiliteracies approach for democracy. *International Journal of Technology and Design Education*, 19(3), 237–254.

Study of correlations between treatments of the didactic incidents and interactive decisions. Case of a technological teaching session in a Tunisian middle school.

Nour ElHouda Essefi



Nour El Houda Essefi
Virtual University of Tunisia
Tunisia
ennour@yahoo.fr

ABSTRACT

The field of didactics places great importance on teacher practices in the classroom. Teachers must be ready to address unforeseen circumstances that might crop up in the interaction of class. The focus of this study (located in a hermeneutic epistemology) is on carrying out the correlations between the importance of the perception and the deal with the unforeseen events (Jean, 2008; Huber&Chautard, 2001; Perrenoud, 1999; Benaïoun-Ramirez, 2009...) and interactive decisions (Tiberghien&al, 2007; Sensevy, 2007...) that may exist between them and the construction of the knowledge taught in the classroom (Mortimer, 2007; Tiberghien&al2007...). In this study, we filmed a technological teaching session at a Tunisian middle school. We used video processing software (Transana), we subdivided this session into discursive elements that were analyzed statistically to check out if there are any correlations between dealing with the didactic unforeseen and the chronological management of knowledge in the classroom. Thus, we show that in dealing with the didactic unforeseen, the teacher lingers on the knowledge and articulates by a call of a notion (especially during the explanation), an announcement or an advance of content. Our study led us to get insights into the way the content was introduced to the learners and how the teacher carried out the various tasks, irrespective of their academic and professional training.

Keywords: Teaching practices, interactive decision, unforeseen, modalities of treatments, technology education.

Introduction and research problems

A number of studies in didactics focus their interest on teacher practices (Carnus, 2001; Marcel & Al, 2002; Riff & Durand, 1993; Sensevy, 2007) in interacting with knowledge-based students. Given the dynamics of interaction, disruptive situations arise called unforeseen (Jean, 2008; Huber & Chautard, 2001; Perrenoud, 1999; Benaïoun-Ramirez, 2009...).

This study focuses on the importance of the perception and the way unforeseen situations are addressed (classified as didactic, because they intervene during the transmission of knowledge). The study examines the effects on interactive decisions (chronogenetics) to understand the articulation and pace of knowledge conveyed by the discourse.

The study seeks to answer the following research question:

- What are the correlations between the treatment modalities that a teacher implements in the face of didactic unforeseen, and the decisions to characterize the pace and articulation of the knowledge taught?

In a descriptive and comprehensive approach, we will determine how to deal with the contingencies, then we will try to characterize the decisions taken in class by a technology teacher, to determine its chronological management of the knowledge taught.

Theoretical framework

Our theoretical framework emerges from two lines of research; one deals with the study of contingencies and their treatments; the other is about teaching practices.

Unforeseen

Several studies agree that the unexpected is a pervasive notion within the teaching/learning situation (Hubert & Chautard, 2001; Jean, 2008; Perrenoud, 1999; ...).

Bénaïoun-Ramirez (2009) defines the unexpected as a disruptive incident that arises in the classroom, without having been foreseen in the context of uncertainty for the subject it disturbs; it depends on both the context and the teacher.

The works presented by (Huber & Chautard, 2001; Jean, 2008; Marcel, 2004) link the origins of the unforeseen to the pupil, the teacher, time management, last-minute educational opportunities and institutional constraints.

Therefore, and for our study, we will adopt the dimensions distinguished by the work of Bénaïoun-Ramirez (2009):

-the contextual unforeseen: related to the scope of activities, the organization, the institution...

-The pedagogical unforeseen: philosophical or ideological (related to the mission of the teacher), of life and class conduct (in relation to time management, students), or relational unforeseen (student behaviour).

- The didactic unforeseen: it refers to knowledge, it is either related to the students (the questions they ask, the different ways they propose), or related to the teacher (his predictions, his missed acts...).

In addition, we focused on the observation made by Bénéïoun-Ramirez & Panissal (2010), which then links these didactic unforeseen events related to the student, to the cognitive incidents defined by Huber (2007), as long as what comes into play in both cases, it is the construction of knowledge.

As they are, unforeseen events occurred in the classroom, place the teacher under the obligation of acting in an emergency, and deciding in uncertainty (Perrenoud, 1999).

Dealing with unforeseen events

To deal with unforeseen in the classroom, teachers use tricks, tactics, strategies, or tinkering Bénéïoun-Ramirez (2009). As a result, some people experience the situation poorly, others benefit from it (Jean & Etienne, 2011; Bronner, 2009).

Bénéïoun-Ramirez (2009) present the notion of improvisational performance, which corresponds to the treatment of an unforeseen with relative character (where uncertainty is mainly about the moment) by routines integrated by the teacher (Tochon, 1989). If the unforeseen is radical (where the event itself is within the conceivable limit), the teacher uses what Perronoud (1999) defines as settled improvisation, or to do with mentioned by Bénéïoun-Ramirez (2009).

Jean (2008) conceptualizes the management of the unforeseen as an evolution of the triptych unforeseen/phenomenon/event, registered it in the problematic of professional gestures of Bucheton (2009). The teacher perceives the unforeseen, but decides to ignore it or transforms it into what is called event. Jean (2008) also mentions that the teacher will perceive the unforeseen as a phenomenon, so that it is brought to everyone's attention; which in a second case can be transformed into a periphenomenon and treats it to the sight of the whole class.

Huber & Chautard (2001) show that unforeseen treatments are focused on the concept of pedagogical judgement in the act, experiential and on the act. Thus, these authors model the management of the unforeseen and they identify the following treatments: re-question, dodge or put back, take an inappropriate or adapted behaviour for learning.

This review will help us to explain how the teacher confronts the unforeseen. The understanding of this confrontation will be highlighted through the language practices of teachers; which are understood as the conducts allowing the exchange, the expression of thoughts and communication through a verbal and nonverbal system; where teachers aim at conceptualization and face unforeseen events (Bénéïoun-Ramirez & Panissal, 2010). It is at these moments of confrontation that we focus our study, and their influence on teaching practices.

Teaching practices

This work is under the umbrella of the socio-constructivist paradigm (Marcel & Al, 2002), within the teaching/learning process, where teachers and students interact in a complex, constantly changing social context that is established through a discourse between these actors centered on the knowledge to be taught (Badreddine, 2009).

The teacher, leader of the interactive speech, produces decisions at different scales: pre-or pro-interactive, interactive and retro-interactive (Riff & Durand, 1993).

Interactive decisions presented by Carnus (2001) as decisions generated during a session where the teacher faces a dynamic environment.

These decisions will be studied by referring to Sensevy's (2001) conceptual framework of didactic action as a joint action between the teacher and the students centered on the knowledge presented itself as the object of the didactic transaction which is governed by a contract (Brousseau, 1998), and conceived from the didactic game (Sensevy, 2007).

This game is described from three descriptors: mesogenesis, topogenesis, and chronogenesis (Sensevy, 2007). We use this last descriptor, since it refers to the scrolling of knowledge along the time axis in the classroom (Chevallard, 1991; Mercier & Schubauer-Leoni, 2005). Indeed, the pace at which new knowledge is introduced depends on both the teacher and the pupils, and as a result of the class system, which gives this descriptor its evolutionary character (Tiberghien & al, 2007).

By knowledge we mean the taught knowledge defined by Chevallard (1991), where the knowledge to be taught, fixed in texts, which is structured and personalized by teacher, will correspond to the classroom knowledge developed by the teacher and students during the teaching sequence (Tiberghien & Al, 2007). That's what we're trying to relate to the decisions the teacher has made to teach the students.

In this study, this relationship will be established by the restitution of knowledge over time. These decisions will be analyzed on a microscopic scale that represents a fine level of granularity of the order of a minute and a second, this scale being that of statements or gestures of people (Tiberghien & Al, 2007).

Methodology of video data collection

In our study, we analyze the temporal coherence of the teacher's decisions and those relating to the articulation of the taught knowledge after the treatment of the unforeseen (chosen didactic). Therefore, we have used video data collection tools of the activity in the classroom in order to process them retrospectively, since this video trace ensures the real unfolding of the situation as it is (Badreddine, 2009).

The context of the research is presented in Table 1.

Table 1: Research Context

The establishment	A public institution located in Tunis (Tunisia) It is a pilot middle school, which students access by having an overall grade 16 in the national exam of the sixth end of the primary cycle. (The elitist character is not considered).
The class	A group of seventh grade pupils (half-class) consisting of twelve 12-year-old students, three girls and nine boys. The session lasts 90 minutes per group and per week. The collected sequence lasts (57min 21s). The teacher started the session with a 20-minute written test.
The teacher	The 33-year-old teacher has a master's degree in civil engineering. He has been teaching for eight years, after passing CAPES (Aptitude Contest for Secondary Education).
The course taught in this sequence	The course chosen is the functional analysis, which aims to determine the service functions of a technical system. This course is part of the subject of technological education at the Tunisian middle school taught in Arabic. Which led us to translate from Arabic to make the transcription.

We filmed the session chosen with a digital video camera and a microphone for sound recording during student interlocations; and it was placed at the back of the class diagonally. Another microphone was attached to the teacher's apron. All recorded data was compressed using Windows Movie Maker software and converted to a ".wmv" file.

Methodology of analysis of collected data

First, we did the complete transcription of the video using the Transana software. Then we do the synopsis of the session by adopting the one made by Sawayssi (2005), which helped us to do a thematic dividing that allows to ask on the articulation of the chronogenetic decisions and the concentration of the different types of unforeseen inside themes and sub-themes.

Then, we divide the session in episodes based on the verbal and nonverbal criteria defined by Mortimer & Ai (2007). Following this dividing, and after several screenings of the session, we proceeded to the identification of the various decisions, unforeseen and their treatments.

For the identification of a decision, we followed the model established by (Buty & Badreddine, 2009) which postulates that a decision must have three attributes; a reason(s), an indicator and a result.

For the consideration of decisions related to the management of the content taught in a single session, we will adopt the typology developed by Scott (1998). It characterizes the pace of the class where the teacher decides to linger or progress in the taught knowledge. The second dimension makes it possible to trace, from the microscopic scale, the sequence and the articulation of the content of the taught knowledge. Buty & Badreddine (2009) presents five types: postpone, announce, advance, call and recall a content.

Following what has been established, we use the indicators and markers (surprise, delay, misunderstanding, etc.) introduced in the work of Bénaïoun-Ramirez (2009) to identify didactic unforeseen events and cognitive incidents, as well as the language practices and markers (in terms of faces, voices and words) issued by Hubert & Chautard (2001).

As for identifying the treatment of unforeseen events implemented to regulate the conduct of the class, we have constructed a formalization of the modalities (renounce, avoid, explain, rectify, hesitate, etc.) of treatment of didactic unforeseen events based on the work of Bénaïoun-Ramirez (2009).

This work resulted in a three fold identification:

- The moment of occurrence and the duration of the unforeseen in minutes and seconds.
- The origin of the unforeseen (pupil, teacher).
- The treatment of this unforeseen by the teacher, in binary terms (accounted or ignored), and in terms of the types of treatment and the modalities he presents (without seeking their relevance: what he's doing, not what he should do).

Note that for convenience, we use abbreviations (IC) for Critical Incidents, (ICog) for Cognitive incidents and (IPVd) for Didactic unforeseen (Bénaïoun-Ramirez 2009).

Results and discussions

The identification of the unforeseen

Identifying contingencies by dividing of the session into episodes shows that 46% of the class time was devoted to the treatment of the unforeseen. These results are confirmed by those developed by Jean (2008) who found between 50 and 85% of the class time was devoted to the treatment of these unforeseen events. The thematic division shows that the topics, discussed at the beginning of the session, are the most solicited by didactic unforeseen, generated mainly by pupils' cognitive incidents. The identification carried out shows that the teacher encountered pedagogical and didactic unforeseen during the session.

The table below detail the different types of decisions made for each type of unforeseen identified in the session.

Table2: Percentage of Types of Decisions by Type of unforeseen

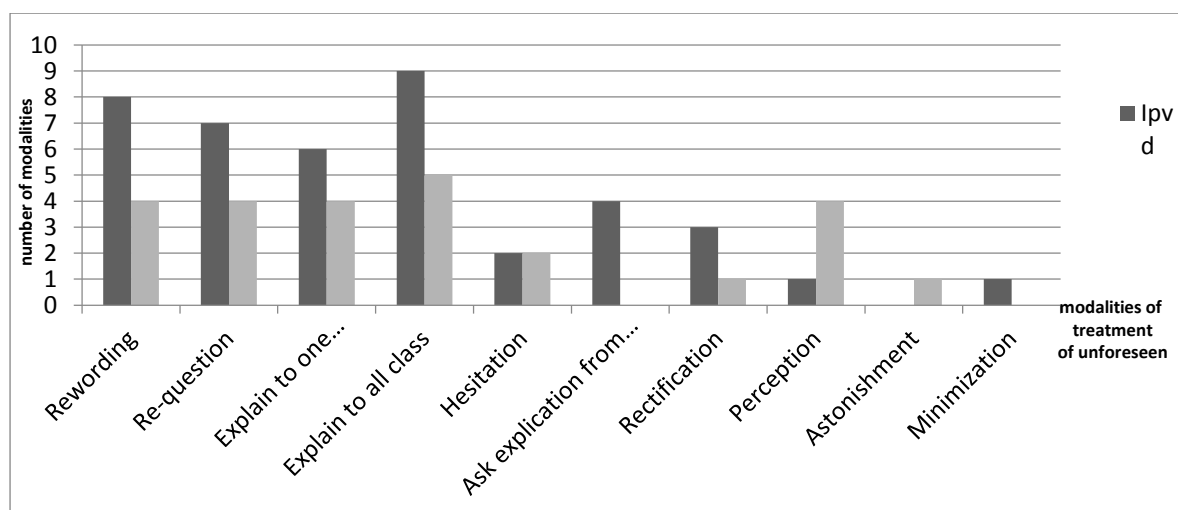
		Decision for the rhythm of knowledge		Decision for the articulation of the content of knowledge					Total	percentage
		Progress	linger	call	Advance	Postpone	Recall	Announce		
Types of unforeseen	Didactic	9	21	9	6	3	1	8	57	43%
	Pedagogic	24	1	4	6	2	2	8	47	36%
	Cognitive incident	4	10	6	1	1	1	5	28	21%
	Total	37	32	19	13	6	4	21	132	100%
	percentage	28%	24%	15%	10%	5%	3%	15%	100%	

Through these results, we find that during the didactic unforeseen teacher proceeds by lingering on content then a call and an announcement or advance. This same type of process is carried out during the occurrence of critical incidents; that is explained by the fact that more than 50% of the didactic unforeseen are generated by student's cognitive incidents.

The identification of the modalities of treatment of didactic unforeseen

The numbers of treatment modalities issued by the teacher are grouped by the type of unforeseen as shown in figure 1.

Figure 1: Modalities of treatment of didactic unforeseen



These results show that the most frequent modalities are explaining to all class or to one student; they appear mainly in the treatment of didactic unforeseen generated by cognitive incidents. Moreover, these two modalities are accompanied in large part by their appearances by reformulations and re-questions; hence the proportionality of the results found. This is explained by the fact that the same unforeseen can receive a plural response (Benaïoun-Ramirez, 2009). Thus, these treatments reflect that the teacher uses his perception of the unforeseen as a phenomenon and transforms it into periphenomenon (Jean, 2008); thus referring to improvisational performance in the face of relative unforeseen (Bénaïoun-Ramirez, 2009).

On the other hand, if modalities of minimization, rectification or hesitations are implemented in the face of a dynamic sequence of unforeseen events, they come under dimension to do with the radical unforeseen (Bénaïoun-Ramirez, 2009). In other cases, the teacher has more

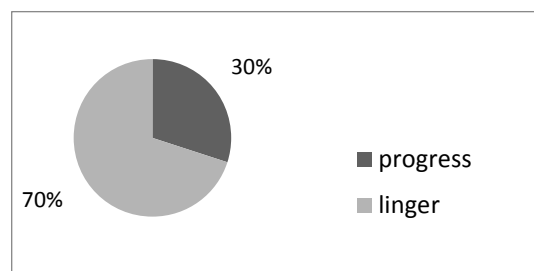
opportunities to use unforeseen as opportunities to implement didactic work (Bénaïoun-Ramirez, 2009).

Study of temporal decisions according to the treatment of didactic unforeseen

The results show that most of the temporal decisions are taken by the unforeseen. The following figures explain that the teacher builds knowledge through didactic unforeseen by deciding to linger on the content of knowledge.

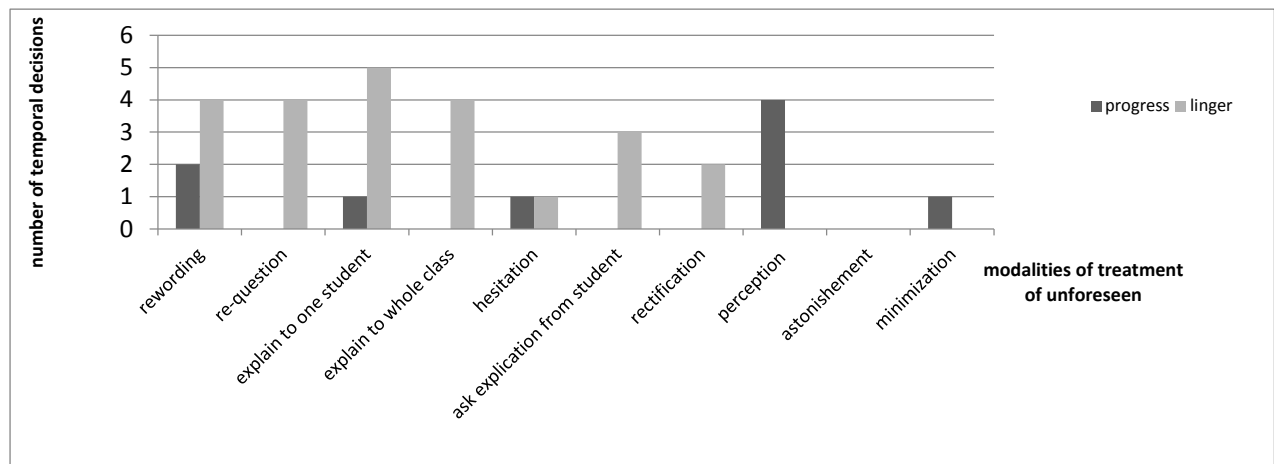
The figure 2 present the percentage of components of temporal decisions following didactic unforeseen

Figure 2: Percentage of components of temporal decisions following didactic unforeseen



The figure3 presented below details this construction of knowledge, with the various treatment modalities granted to didactic unforeseen.

Figure3: Distribution of temporal decisions according to the modalities of treatment of the unforeseen

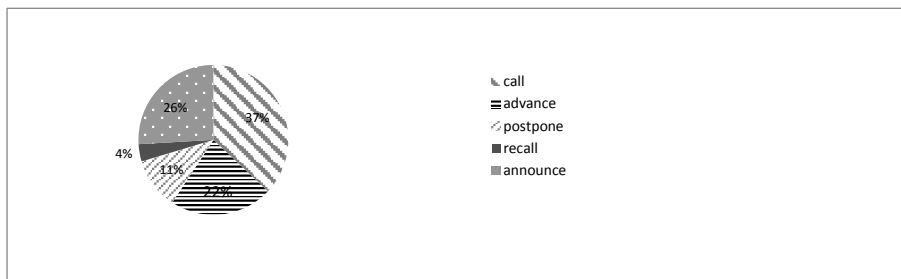


This distribution shows that the teacher lingers during the modalities of reformulation, re-question, explain to a student and mainly when she explains to the whole class. We can refer this result because the observed subject treat the pupil's erroneous answers by asking questions to the whole group, so that the students understand the nature of their errors and advance in the appropriation of their knowledge. The same distribution shows that the teacher progresses when he decides to unthread the unforeseen and leave it in the dimension of simple perception.

Study of decisions for articulation of knowledge according to the treatment of the didactic unforeseen

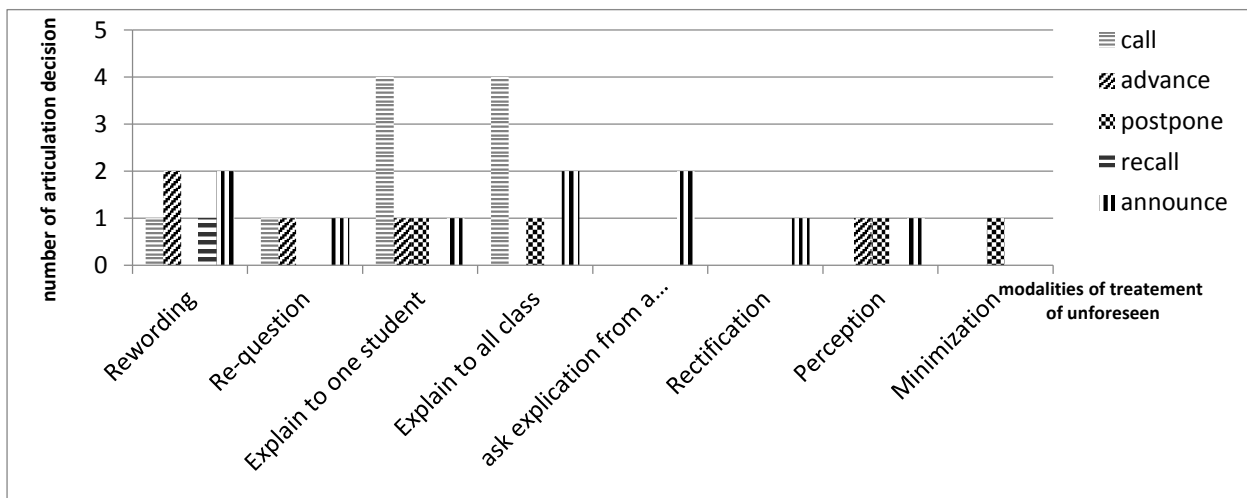
The results also show that decisions on the articulation of taught knowledge are made mostly at the precipice of unforeseen. The figure4 shows that the teacher constructed knowledge, in the occurrence of didactic unforeseen, by making a call, generally, of a notion followed by an announcement or advance.

Figure4: percentage of components of knowledge articulation decisions following didactic unforeseen



In figure 5 below, we present the construction of knowledge in terms of the different treatment modalities for didactic unforeseen or cognitive incidents.

Figure 5: Distribution of articulation decisions according to the unforeseen treatment modalities



This distribution confirms that, among the most frequent treatments explained to the student or class, the teacher decides to make a call followed by an advance or announcement. The decision to appeal, usually a concept, occurs as a result of all of these modalities.

The variation with the found results is shown by the decisions in advance or announcement. The treatments are then accompanied, in their minority, by decisions where the teacher proceeds to postpone content.

Through the modalities of reformulation and re-questioning, the teacher sets up the same articulation decisions in proportion. This is due to the fact that these modalities are interdependent and that they can be both a response to the same unforeseen. Most of, the teacher then makes a call followed by an advance or announcement, during the treatment of didactic unforeseen.

She perceives the unforeseen without giving it importance, and by that she proceeds by advancing or announcing or postponing content.

Conclusion

Our approach aims to understand and analyze teaching practices in the face of the unexpected. We used a methodology to identify and crosscheck the different components of the process by which the teacher means his actions in context.

The results showed that the restructuring of the teacher's discourse on the content taught was partly related to the treatment of unexpected events identified by the researcher.

Thus, we have shown that in dealing with the didactic unforeseen, the teacher, in general, lingers on the knowledge which is articulated by a call of a notion especially during the explanation, an announcement or an advance of content.

This shows that the teacher follows his planning and tries to finish all the examples he has planned, while ensuring that students understand the nature of their mistakes and advance in the appropriation of their knowledge.

Through our study, although it could have been enlightened by complementary interviews with the teacher, we have identified the impact of unexpected treatments on the chronological management of knowledge in the classroom. This can provide, in the context of the professionalization of education, descriptors that can contribute to the creation of training schemes for apprentice teachers.

References

- Badreddine, Z. (2009). *Étude des décisions chronogénétiques des enseignants dans l'enseignement de la physique au collège*. Doctoral Thesis, France, Université Lyon.
- Bénaïoun-Ramirez, N. (2009a). *Faire avec les imprévus. Représentations professionnelles et construction de la professionnalité enseignante*. Lyon : Chronique sociale.
- Bénaïoun-Ramirez, N. (2009b). Identités professionnelles entre réflexivité et adaptation : histoire de vie professionnelle de Maîtres-Formateurs. *Recherche et Formation*, 60, 135-150.
- Bénaïoun-Ramirez, N., & Panissal N. (2010). *Mise en œuvre d'une démarche constructiviste d'enseignement : analyse croisée de corpus*. Paper presented at the Congrès International d'Actualité de la Recherche en Education et en Formation AREF, Genève, Suisse.
- Brousseau, G. (1998). *Théorie des situations didactiques*. Grenoble : la pensée sauvage.
- Bronner, A. (2009). L'analyse du travail didactique du professeur dans la classe. In Bucheton, D. (Dir.), *L'agir enseignant : des gestes professionnels ajustés* (pp. 159-173). Toulouse, France: Octarès.
- Bucheton, D. (2009). Le modèle de « l'agir enseignant et ses ajustements ». In Bucheton, D. (Dir.), *L'agir enseignant : des gestes professionnels ajustés* (pp. 25-69). Toulouse, France: Octarès.
- Buty, C. & Badreddin, Z. (2009). Quelques effets didactico-discursifs de l'utilisation des schémas dans un enseignement d'électricité. Aster, n°48.

Carnus, M.-F. (2001). *Analyse didactique du processus décisionnel de l'enseignant de l'EPS en gymnastique. Une étude de cas croisés*. Doctoral Thesis, France, Université de Toulouse III.

Chevallard, Y. (1991). *La transposition didactique*. Grenoble: La Pensée Sauvage.

Huber, M., & Chautard, P. (2001). *Les savoirs cachés des enseignants. Quelles ressources pour le développement de leurs compétences professionnelles*. Paris: L'Harmattan.

Huber, M. (2007). Stratégie spontanée et stratégie réfléchie dans la gestion des interactions verbales. In Specogna, A. (Dir.): *Enseigner dans l'interaction* (pp. 123-136). Nancy, France : PU Nancy.

Jean, A. (2008a). *La notion de « gestes professionnels » : entre analyse de l'activité, épistémologie et ingénierie de formation*. Paper presented at the Journées d'étude inscrites comme colloque associé aux Deuxièmes rencontres scientifiques universitaires Montpellier-Sherbrooke, Montpellier, France.

Jean, A., & Etienne, R. (2011). *L'analyse des traitements des imprévus au service du développement professionnel des enseignants*. Paper presented at the Colloque International INRP sur le travail enseignant au XXIe siècle Perspectives croisées : didactiques et didactique professionnelle, Lyon, France.

Marcel, J-F. Orly, P. Rothier-Bautzer, E. & Sonntag, M. (2002). Les pratiques comme objet d'analyse. Note de synthèse. *Revue française de pédagogie*, 138, 135-170.

Marcel, J-F. (2004). Les pratiques enseignantes de gestion des imprévus. *Psychologie et éducation*, 56, 31-50.

Mercier, A., Schubauer-Leoni, M.-L., Donck, E. & Amigues, R. (2005). The Intention to Teach and School Learning: The Role of Time. In: A.-N. Perret-Clermont. *Thinking Time A Multidisciplinary Perspective on Time*, USA, Canada, Switzerland: Hogrefe & Huber, 141-154.

Perrenoud, P. (1999). Gestion de l'imprévu, analyse de l'action et construction de compétences. *Éducation Permanente*, 140, 123-144.

Riff, J., & Durand, M. (1993). Planification et décision chez les enseignants. *Revue française de pédagogie*, 103, 81-107.

Scott, P.H. (1998). Teacher talk and meaning making in science classrooms: A Vygotskian analysis and review. *Studies in Science Education*, 32, 45-80.

Sensevy, G., Mercier, A., & Schaubert-Leoni, M. L. (2000). Vers un modèle de l'action didactique du professeur. A propos de la course à 20. *Recherches en didactique des mathématiques*, 20 (3), 263-304.

Sensevy, G. (2001). Théories de l'action et action du professeur. Dans : Jean-Michel Baudouin éd., *Théories de l'action et éducation* (pp. 203-224). Louvain-la-Neuve, Belgique: De Boeck Supérieur. doi:10.3917/dbu.baudo.2001.01.0203.

Sensevy, G. (2007). Des catégories pour décrire et comprendre l'action didactique. In G. Sensevy & A. Mercier. (Dir.): *Agir ensemble : Éléments de théorisation de l'action conjointe du professeur et des élèves* (pp.13-49). Rennes, France : Presses Universitaires de Rennes.

Tiberghien, A., Malkoun, L., Buty, C., Souassy, N., & Mortimer, E. (2007). Analyse des savoirs en jeu en classe de physique à différentes échelles de temps. In G. Sensevy & A. Mercier.

(Dir.): *Agir ensemble : Éléments de théorisation de l'action conjointe du professeur et des élèves* (pp.73-98). Rennes, France : Presses Universitaires de Rennes.

Tochon, F. V. (1989). La pensée des enseignants : un paradigme en développement. *Perspectives documentaires en sciences de l'éducation*, 17, 75-97.

The truth is in the boat: A case study of pedagogical content knowledge and technical skill development in pre-service technology education teachers.

David Gill



David Gill
Memorial University of Newfoundland
Canada
dgill@mun.ca

ABSTRACT

This paper outlines the preliminary findings of a study focused on the impact an expert teacher's pedagogical and technical knowledge and skill may have on the pedagogical and technical development of pre-service technology education teachers. Specifically, this inquiry falls within the context of traditional wooden boat building in Newfoundland and Labrador, Canada. Understanding the relationship between an expert's knowledge and skill, and the development of a novice's knowledge and skill is vitally important for institutions charged with graduating technology education teachers. Exploring the impact of pre-service teachers' pedagogical and technical development was considered in relation to an expert teacher's pedagogical content knowledge, and the nuance between declarative and procedural knowledge within technological activity. Data were collected from semi-structured interviews and session observations. The sample was purposeful as the participants were recruited from boat building workshops between 2017 and 2019 and the 2017-2018 technology education diploma program cohort from Memorial University. Thematic analysis was used to identify major themes within the data. An analysis of the data appears to indicate that interpersonal relationships are critical for the development of pre-service teacher technical and pedagogical knowledge and skills.

Keywords: PCK, technical knowledge and skill, pre-service technology education teachers

Research on technology education teachers' beliefs and practices has indicated that there is a difference in their understanding of the nature of content knowledge as compared to other subject area teachers (Doyle, in press). While teachers of other subjects may focus on concepts and knowledge acquisition in their pedagogical practice, technology education teachers still focus on technological activity with less emphasis on conceptual knowledge (Doyle, in press; Jones, Bunting, & de Vries, 2013; Williams & Lockley, 2012). How teachers' know and enact their practice has been described through various interpretations of pedagogical content knowledge (PCK) for the last three decades. While PCK was framed as the intersection of teachers' subject matter knowledge, pedagogical knowledge, and context knowledge that informed practice (Shulman, 1986), this concept has matured. Moving away from the notion of general teaching practice the idea of situating PCK within specific teachers' experiences has emerged (Doyle, in press). This evolution of thought on PCK may have a direct effect on technology teacher pre-service education. As de Miranda (2017) has suggested, individual technology education teachers have their own unique domain specific knowledge and any hope of transmitting this to pre-service teachers is probably near impossible. Rather, as pre-service technology researchers and educators there is an opportunity to generate and evaluate useful pedagogical practices for the conceptual strains of technology education. This paper will discuss the preliminary findings of a study focused on the impact an expert teacher's pedagogical and technical knowledge and skill may have on the pedagogical and technical development of pre-service technology education teachers. This inquiry was framed within the context of traditional small wooden boat building in Newfoundland and Labrador, Canada.

Context

Wooden boat building was once common in Newfoundland and Labrador, Canada, but the advent of new synthetic materials, processing methods, and the demise of the inshore fishery have all taken a toll on this traditional knowledge and skill. With no ties from the past to connect to the present, or plans to reach into the future, wooden boat building in Newfoundland and Labrador may be lost. Shils (1981) noted traditions that survive the test of time are those that evolve and adapt to changing conditions. As a way to adapt and expose pre-service technology education teachers to this specific knowledge and skill the Faculty of Education of Memorial University and the Wooden Boat Museum of Newfoundland and Labrador have jointly offered winter boatbuilding workshops for the past three winters (2017-2019). The workshops have provided an authentic and context specific technological activity for pre-service teachers to develop their pedagogical and technical expertise by learning from an expert.

Literature Review and Theoretical Background

It has been suggested that superior human performance is predominantly acquired through experience (Ericsson & Smith, 1991) and that "expertness lies more in an elaborated semantic memory than in a general reasoning process" (Chi, Glaser, & Farr, 1988, p. xxxv). Context matters, and while multiple theories and frameworks have been utilized to study the difference between expert and novice performance, similar findings persist. Experts in any domain tend to focus on solutions rather than problems and have a better understanding of the complex nature of systems as compared to novices. (Dixon & Johnson, 2011; Hmelo-Silver & Pfeffer, 2004). While continued and sustained experience is key to developing expertise, it should be noted that individual preferences and interests along with motivation

and practice counters the idea that anyone can achieve expertise in any domain with just practice alone (Chi et al., 1988). To understand the development from novice to expert technology education teacher there should be an acknowledgment of the potential relationship between interest, motivation, practice, and experience within the technical and pedagogical realms along with technical and pedagogical knowledge and skill.

Subject matter knowledge or content knowledge in technology education is still problematic as it encompasses not only declarative knowledge, but also procedural knowledge. In its broadest sense, technology is a normative practice (Jones et al., 2013) with practitioners relying on both an understanding of declarative and procedural knowledge –what Ryle (1949) originally described as the difference between “knowing that” and “knowing how” (p. 28-29). The relationship between declarative and procedural technical knowledge was difficult to analyze before the professionalization of technological communities as this knowledge was generally diffused through master apprentice interactions (Laudan, 1984). As de Vries (2005) has stated “textbooks are no option for teaching and learning knowledge that cannot be adequately expressed in propositions” (p. 47). Therefore, the act of learning through doing is important for developing proficiency in understanding both knowledge and skill. The relationship between the declarative and procedural or the cognitive and the tacit presented in technological activity forms a constant tension –a tension that pre-service technology education teachers must come to understand as they develop their own PCK.

As mentioned earlier PCK has now been theorized to be more than the collective teaching practice of a specific domain. The idea that there are multiple layers between general and individual PCK has allowed researchers to propose more nuanced methods for investigating PCK (Doyle, in press; de Miranda, 2017; Gess-Newsome, 2015). One such idea is pedagogical content knowledge & skills (PCK&S). Gess-Newsome (2015) defined PCK as personal knowledge that teachers use to design and reflect on instruction within context. This idea can be related to the context and domain specificity of the development of expertise – that expertise, in this case teaching expertise, is context bound. Gess-Newsome (2015) also defined PCK&S as the “act of teaching” (p. 36) and this differentiates between what a teacher knows (“knowing that”) and what they are able to do (“knowing how”). PCK&S is the embodiment of PCK within context. As such, it is the dynamic enactment of a teacher’s ability to implement instruction, monitor student activity, and adjust their action based on *in situ* feedback. How pre-service technology education teachers’ experience, reflect on, and perceive an expert teacher’s PCK&S will influence their own development and forms the context of this study.

Conceptual Framework

Based on a review of the literature a conceptual framework (figure 1) was developed to help guide the data collection and analysis for this study. As there are issues of separating knowledge from skill, the pedagogical and the technical have been isolated along the middle axis with bidirectional arrows indicating a strong relationship between both. As a technology teacher’s experience increases within the pedagogical and technical domains so does there expertise as illustrated by the upper triangle. For pre-service teachers, the framework is mirrored on the bottom with the addition of “shared experience” illustrating their interactions with the expert teacher helping their development within the pedagogical and technical domains. As the expert teacher implements a technical lesson he also implicitly delivers a pedagogical lesson within the context of a technological activity. This framework helped conceptualize the potential relationship between an expert teacher’s pedagogical and

technical knowledge and skill in relation to the development of pre-service teachers' pedagogical and technical capacity.

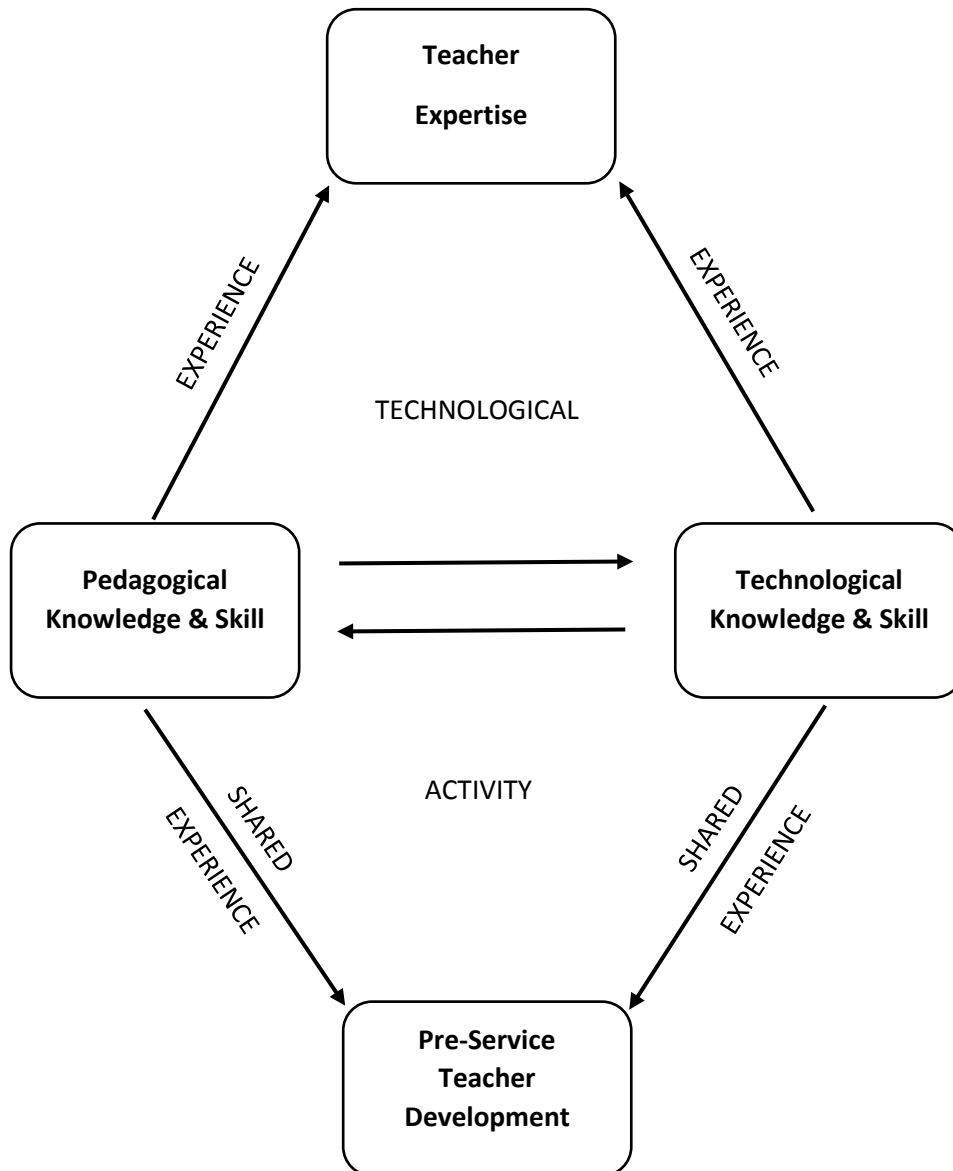


Figure 16: Expert and pre-service teacher expertise development

Methodology

The study is positioned within the qualitative/constructivist paradigm and in particular the case study methodology of Merriam and Tisdell (2016). The following research question guided the inquiry; how does an expert teacher's pedagogical and technological knowledge and skill influence the development of pre-service teachers' pedagogical and technical development?

Participants were selected from a purposeful sample and data were gathered from three one-on-one semi-structured interviews with the workshop's teacher and post workshop interviews with two pre-service technology education teachers –one male and one female. The workshop teacher has more than 40 years of wooden boat building experience and approximately 15 years of teaching experience. The female pre-service teacher has an

English and religious studies background and the male pre-service teacher has a mathematics and computer science background.

Braun and Clarke's (2006) thematic analysis was used as the analytic framework. While reading and re-reading the transcripts preliminary codes and data chunks were created and identified in relation to the research question. These codes were refined through a second cycle as meta-codes were created to facilitate the identification of larger themes. The emerging themes allowed the exploration and development of rich thick descriptions of the relationship between an expert's pedagogical and technical knowledge and skill and pre-service technology education teachers' pedagogical and technical development.

Results

Throughout the workshops the expert teacher put forward the idea that the “truth is in the boat”. That “... the boat in itself, as it comes together, answers the questions”. While some may argue that the idea of “truth” has epistemological issues, from the perspective of the study's technological activity this idea represented what lies at the heart of technical and pedagogical development within the context of pre-service teacher education and traditional wooden boat building. That the technologies we create are much more than the final output of a technical process, they are embedded with an aesthetic that is representative of the technique, values, and culture of a continued time and place. As we literally shape the boat, the boat shapes us. From an analysis of the data the idea of pre-service teachers shaping and being shaped through their interactions within the contextual situation was evident. Three major themes emerged from the data in relation to an expert teacher's influence on pre-service teacher pedagogical and technical development. Interactions and relationships, the influence of technological knowledge and skill, and the influence of pedagogical knowledge and skill. The results of the findings will be discussed within the framework of these three emerging themes.

Interactions and relationships

Interactions and relationships were emphasised by all three participants in this study and can be related back to the idea of shared experiences in the conceptual framework. Three sub-themes emerged from the data in relation to this larger theme: expert teacher to pre-service teacher interactions, peer to peer interactions, and the development of mutually respectful relationships. All three sub-themes were identified as having an influence on both the expert teacher's and pre-service teachers' own technical and pedagogical development.

The interactions between pre-service teachers and the expert teacher were viewed as essential to both groups as they learned and were shaped by one another. This was highlighted when the expert teacher mentioned he still learns from listening to students within context and that “... the student [sic] that are asking the questions sometimes brings your attention to sometimes that proper or more, ah, a better way...” The importance of these interactions and allowing the freedom to question methods and procedures actually can reinforce pedagogical and technical practice while allowing pre-service teachers to build their own. These types of interactions can be viewed as the building blocks of developing relationships between teacher and students.

Peer-to-peer interactions were also facilitated by the expert teacher. As participants formed groups naturally he always monitored to make sure no one person was dominating the action. There is little benefit in pre-service teachers developing their own technical skills if

they only watch others, they must also do. As it is the expert teacher's belief that "... action will reinforce the lesson" he made an effort to move participants from group to group "... to make sure that they have to do the action because the action is going to complement the knowledge..." This idea is a concrete example of the expert teacher's self-awareness of the interconnection between declarative and procedural knowledge that has been identified as key in developing expertise in a domain.

From a pre-service teacher perspective the idea of building solid relationships emerged as an important factor influencing their development. Both pre-service teachers felt that without building trusting relationships learning can be hindered. This idea was succinctly illustrated when the first pre-service teacher mentioned the impact of casual personal interaction had on her experience when she said that "... just building that relationship made me trust him and trust what he was telling me even more when it came to him passing on an instruction". These seemingly simple and mundane experiences also provided a platform for the expert teacher to gain insight into the technical background of participants. This information can be invaluable for pedagogy in practice or what Gess-Newsome (2015) called the "act of teaching" (p. 36). As the second pre-service teacher commented, a teacher understanding the dynamics of a classroom "... comes back to knowing your students. Knowing how well they're doing, what their skill level is, what their comfort level is." These data would indicate that simply more than technical and pedagogical skills are at work in influencing pre-service teachers' development. It would appear that the interpersonal may have a significant role as well and therefore should not be overlooked in pre-service technology education programs.

Influence of technical knowledge and skill

The importance of having or gaining a solid understanding and experience with the techniques of the contextual technical domain was a prominent theme that emerged from the data. As Shulman (1986) stated, pedagogy without content knowledge is not adequate. It is difficult to separate the technical from the pedagogical as the data would suggest an interplay exists between the two. Two sub-themes related to technical knowledge emerged from the data: expert and pre-service teacher technical perceptions. Each of these themes lends insight into how an expert teacher's technical knowledge and skill may influence the development of pre-service teachers.

From the expert teacher's perspective, his educational and practical experience has had a significant influence on his understanding of the declarative and procedural knowledge associated with wooden boat building and how to teach. He explicitly recognized the importance of multiple forms of knowledge and the relationship between conceptual and tacit. While he stressed the importance of declarative knowledge in understanding the concepts involved, he also noted "... you have to do, you have to use your hands, you have to use your mind, you have to, you know, but in particular you have to build". This is an explicit example of the tension between "knowing that" and "knowing how" and the expert teacher also explicitly illustrated this when he described the inadequacy of words and metaphors in teaching specific techniques.

The expert teacher's self-awareness of these knowledge representation tensions are important in understanding the difficulty of pinning down content knowledge within technology education. This self-awareness has developed over many years as the expert teacher described a familiarity that allows him to fluidly make design and technical decisions. This idea relates to Dixon and Johnson's (2011) idea that experts can make connections to

common conceptual structures across disparate surface features while working in problem spaces whereas novices cannot.

Pre-service technology education teachers reported developing greater confidence and ability with both general and specific technological knowledge throughout the workshop. The second pre-service teacher remarked that his comfort level with various techniques and tools had increased through a combination of one-on-one and group instruction, and individual practice. Both pre-service teachers stressed the importance of understanding the sequence of a technical process before assimilating that process into the bigger whole. As pre-service teacher one stated:

I like steps. Like, if I can break something down, but I can't do a step if I don't see the purpose of the whole thing. So, I want a big picture, I want to see that we're making a boat, but OK now let's break it down and we're going to do the keel first and this is how we do it. So, here's five steps to making the keel. Let's go and get it together, and then I'll take you back and we'll relate it to the big picture for the next step.

Throughout the course of the workshop both pre-service teachers relied on the experience and pedagogical practice of the expert teacher as a model for building their own technical expertise moving forward. The pre-service teachers also related that they were constantly thinking about how their new technical knowledge and skills could be applied to their own classroom situations in the future.

The data would suggest that students found procedural aspects within the context of the expert teacher modeling techniques as useful for developing their own technical knowledge and skill. While the students did not directly discuss the explicit nature of technical knowledge, their ability to conceptualize the whole in relation to its parts may indicate a starting point for bringing such ideas into their own pedagogical practice.

Influence of pedagogical knowledge and skill

Understanding student expectations and prior skill and experience was emphasised by all three participants in the study as a key theme related to developing pedagogical knowledge and skill. Two sub-themes emerged from the data in relation to this larger theme: Relationship building, and the importance of modeling and reflecting on pedagogical practices. The data analysis highlighted that these sub-themes had an influence on pre-service teachers' pedagogical development.

The expert teacher gave ample opportunity for the pre-service teachers to observe his use of interpersonal relationships and questioning as a part of his pedagogical practice. The importance of developing this type of learning environment was reiterated by the first pre-service teacher who emphasised the significance of building a trusting relationship and the idea of having empathy for future students when she reflected on her initial introduction to the group:

We all stood around and like the 20 of us that started, we all had a bunch of different backgrounds, and experiences, and skill levels with all the stuff, but we were all nervous as hens at first because of everybody, maybe they're better, maybe they thinks [sic] that we're stund [sic] with this tool or whatever. Um, so, just knowing that, like, as a teacher all of my students are going to feel that way too...

She went on to state that it was important to understand that her future students may have similar feelings within technology education courses and that she wished they could come to

her class with an equal technological literacy to ease these types of feelings. This self-reflection within the context of her own experience may be an indication of the potential influence the expert teacher may have had on her pedagogical development as she observed how he mitigated student anxiety through making personal connections.

The second sub-theme deals directly with observation of expert practice in relation to developing pedagogical knowledge and skill. While the expert teacher reflected on multiple learning experiences over his career it was interesting to note the dichotomy in his own pedagogical practice and traditional approaches. He mentioned that many builders were not teachers and much of the instruction could consist of just watching without any explanation. While this was one type of experience in a long list described by the expert teacher in his own path, the second pre-service teacher summed up a negative of this approach when he stated that a "... teacher who knows everything is all well and good, but that doesn't help me if I can't figure it out". He also added that it was opportunities to observe different approaches throughout the workshop and other instances of instruction throughout his technology education diploma that helped him build a context for his own pedagogical practice. He noted that in addition to participating in, and observing the pedagogical practice of the current expert teacher he had the opportunity to:

... add to getting to see how you [author] run a shop, getting to see how GB runs a shop, it was just another experience to sort of add to my list of, well this is – these are ways you can do it, so what works best for me.

This process of reflecting on and contextualizing ones' teaching is an ongoing process as the expert teacher also noted that he is continually refining and looking for better ways to improve his practice. The analysis of the data would indicate that the opportunity to observe and reflect is influential on pre-service teacher pedagogical development.

Conclusion

The notion that an expert teacher's pedagogical and technical knowledge and skill can have an influence on pre-service teachers' development is not a surprising conclusion in and of itself. What is interesting however, is the high level of importance given by the participants on developing interpersonal relationships between everyone involved in a learning endeavour. These relationships were bound within the context of the learning experience and involved not only the expert and pre-service teachers, but were peer-to-peer in nature as well. These interpersonal relationships can be viewed from the perspective of shared experiences as illustrated in the conceptual framework for this study and underscore their importance. The shared experiences not only influenced pre-service teacher development within the pedagogical and technical, but also reflected back on the expert teacher's PCK as well. This is not currently accounted for within the framework, but should be considered moving forward. It would appear from an analysis and discussion of the data that the stronger the relationships within the learning context, the more influential those experiences are on the development of pre-service teachers' own pedagogical and technical expertise. Therefore, the interpersonal can be viewed as complementing both the pedagogical and technical and may act as a catalyst for pre-service technology education teachers' own development. Understanding what accounts for stronger or weaker relationships within the context of pre-service technology education teacher education would be another area of inquiry worth exploring in the future.

References

- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Chi, M. T. H., Glaser, R., & Farr, M. J. (Eds.). (1988). *The nature of expertise*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- de Miranda, M. A. (2017). Pedagogical Content Knowledge for Technology Education. In M. de Vries (Ed.), *Handbook of Technology Education* (pp. 685–698). Gewerbestrasse: Springer.
- de Vries, M. J. (2005). *Teaching about technology: An introduction to the philosophy of technology for non-philosophers*. Dordrecht, The Netherlands: Springer.
- Dixon, R. A., & Johnson, S. D. (2011). *Experts vs. novices: differences in how mental representations are used in engineering design*.
- Ericsson, K., & Smith, J. (Eds.). (1991). *Toward a general theory of expertise*. New York: Cambridge University Press.
- Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK. In P. Friedrichsen, J. Loughran, & A. Berry (Eds.), *Re-examining pedagogical content knowledge in science education* (pp. 28–42). London: Routledge.
- Hmelo-Silver, C. E., & Pfeffer, M. G. (2004). Comparing expert and novice understanding of a complex system from the perspective of structures, behaviors, and functions. *Cognitive Science, 28*(1), 127–138. https://doi.org/10.1207/s15516709cog2801_7
- 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. <https://doi.org/10.1007/s10798-011-9174-4>
- Laudan, R. (Ed.). (1984). *The nature of technological knowledge. Are models of scientific change relevant?* Dordrecht: D. Reidel Publishing Company.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (Fourth Edition). San Francisco, CA: Jossey-Bass.

Ryle, G. (1949). *The Concept of Mind*. University of Chicago Press.

Shils, E. (1981). *Tradition*. Chicago: The University of Chicago Press.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 4–14.

Williams, J. P., & Lockley, J. (2012). *Using CoRes to develop the pedagogical content knowledge (PCK) of early career science and technology teachers*. Retrieved from <http://scholar.lib.vt.edu/ejournals/JTE/v24n1/williams.html>

Pre-service technology education teachers' perceptions of experiential learning through makerspaces.

David Gill, Gerald Galway



David Gill

Memorial University of Newfoundland
Canada
dgill@mun.ca



Gerald Galway

Memorial University of Newfoundland
Canada
ggalway@mun.ca

ABSTRACT

In this paper, we examine the role of makerspaces as a form of co-curricular experiential learning for shaping the pedagogical practices of pre-service teachers. We recruited six (6) pre-service technology education teachers to act as facilitators for a series of intermediate level (grades 7-9) maker sessions, conducted over two semesters, in our technology education facility at Memorial University, Newfoundland and Labrador, Canada. The project was purposefully designed to allow pre-services technology education teachers to interact with their university instructors as well as several in-service teachers during the sessions, within the context of their facilitation roles. Following graduation, we followed up with a sample of four (4) of the (novice) technology education teachers and conducted interviews in relation to their experiences and perceptions in facilitating the sessions with intermediate students. Analysis of qualitative data supports the idea that pre-service teachers perceive maker activities to be a valuable model for independent student learning and a means of shaping their own professional learning and pedagogical practice. Specifically, makerspaces were identified as a strong model for pre-service teacher education within the areas of learning through doing, learning through mentorship, and learning through reflective practice.

Keywords: makerspace, pre-service education, experiential learning

In the early part of the twentieth century, the process of learning to make useful objects was an everyday activity, both in schools and at home. From projects like building a go-cart or constructing a street hockey net to sewing a quilt, children and young adults had ample opportunity to develop useful skills and to co-create with their parents or other mentors in the community. In recent years, there has been a renewal of interest in maker activities. This renewal has created opportunities to experiment with making as a model for experiential learning in pre-service teacher education. Within the context of this resurgence this paper explores potential relationships between making as a form of pedagogy and pre-service teacher education.

Literature Review and Theoretical Framework

Maker education can be thought of as a form of constructivist pedagogy that interprets learning as a highly personal endeavour requiring the learner to initiate the act of learning about technology in its broadest sense (Kurti, Kurti, & Fleming, 2014). Its roots are embedded in the constructivist and collaborative pedagogy of John Dewey and Lev Vygotsky. Dewey (1916) was concerned with interaction, reflection and experience, and his interest was in situating these ways of learning within a community context. Vygotsky (1962) argued that learning is co-constructed under the guidance of teachers or mentors or in collaboration with peers. Papert and Harel (1991) drew on these constructivist principles and proposed a theory of constructionist learning that included the making of “public” artefacts. This learning theory suggests that activities such as making, building or programming can be personally meaningful and are more likely to intellectually engage learners (Kafai & Resnick, 2012).

This study is, therefore, positioned within a qualitative/social constructionist paradigm of inquiry. We conceptualize teaching in makerspaces as a means of mediating the creative processes of designing, constructing (or deconstructing), and/or combining physical or virtual artefacts while utilizing both traditional and emerging methods and tools within a playful, iterative, supportive, and collaborative environment. In a formal education context, teachers are situated as mediators for inquiry-based approaches to the development of knowledge and thinking processes (McWilliam, 2009). How best to implement maker education in formal educational settings is an important consideration for in-service, pre-service, and teacher educators.

While teachers can be situated as mediators within the sphere of makerspaces a tension exists between the emergent informal nature of these activities and formalized education. Since makerspaces have typically emerged from informal learning opportunities as a means of addressing a particular community’s needs, attempts to formalize these experiences may run into difficulty. Cohen, Jones, Smith, and Calandra (2017) noted that while the maker movement has potential for engaging students in formal educational settings, anyone attempting to do so should be cognizant of the divergent nature of makerspaces; there is no definitive ideal. Even though there always have been similar hands-on activities in formal education such as craft, art, and design “...if educators want to integrate these type of maker activities into formal learning contexts it is important to acknowledge the differences between these types of activities, both the purpose of the learning goals and the purpose of the creators’ expression” (Cohen et al., 2017, p. 221). Based on these ideas Cohen et al. (2017) have proposed a simple framework for potentially maintaining the spirit of making within formal education. They theorize that creation, iteration, sharing, and autonomy are key elements that

must be included to sustain the integrity of making as learning. From the perspective of maker education these characteristics are often embedded in structured experiences for learning.

Internationally, experiential learning has been, and remains a prominent component of pre-service teacher education programs generally with the stated goal of increasing teacher candidates' competency (Chambers & Lavery, 2012; Gao, 2015; Hildenbrand & Schultz, 2015; Kang & Martin, 2018). However, experiential learning is not an easy concept to compartmentalize or define. Kolb (2014) stated that experiential learning theory is more than a teaching or instructional method, rather it is a way of knowing and a broad philosophy of learning within the realm of personal experience and reflection. Moon (2004) also highlighted the variations in the interpretations of experience in relation to learning. Experiencing something does not necessarily mean learning will take place, rather experiences can be mediated through formal means to invoke learning. This mediation of concrete experience in relation to reflective observation, abstract conceptualization, and active experimentation is theorized to help in knowledge creation (Kolb, 2014). The distinction between generic experience and experience with purpose has framed our understanding of experiential learning within the areas of maker and pre-service teacher education. As such, we have used the idea of purposeful guided and reflective experience within a specific context as our definition of experiential learning for this study.

Methodology

The purpose of this study was to investigate the perceptions of pre-service technology education teachers about the value of makerspaces, both as a form of experiential learning and a means of professional learning for initial teacher education. In particular, this investigation sought to understand the question: how do pre-service teachers represent the value of co-curricular experiential learning opportunities (makerspaces) in shaping their learning and pedagogical practices?

During the fall and winter of 2016/17 we conducted six makerspace workshops for intermediate level (grades 7-9) students and their teachers in Memorial University's Faculty of Education's Technology Education facilities. Two schools were paired for two full day workshops each, with approximately 40 students in total attending. As university instructors and researchers, we worked with six volunteer pre-service teachers, and several local technology education teachers who helped facilitate the sessions. In each of the sessions students designed and constructed solar powered chargers for personal electronics (smartphones, audio players, etc.). Pre-service teachers from the Faculty of Education's technology education diploma program facilitated safety demonstrations, gave a lesson on computer-aided design and 3-D printing, and developed an electronics assembly guide. In the second session, students used the guide to help them assemble, solder and test the electronics for their solar chargers and build the units. Students worked in pairs, and our pre-service teachers and intermediate teachers provided support and guidance throughout the process.

During spring and summer, 2018, we conducted interviews with a purposeful sample of four pre-service teachers (now having graduated). These interview transcripts were used as the primary source of data for this study. Thematic analysis based on the work of Braun and Clarke (2006) was used to explore and develop insights into the experiential learning

experiences of interviewees within the context of the makerspace sessions. As the interview data was read and re-read, preliminary codes and data chunks were created and identified in relation to the research question. A combination of summarizing words, in vivo, and process coding were used throughout this process. These codes were refined through a second cycle as meta-codes were created to facilitate the identification of larger themes. These themes were then reviewed in relation to the whole data set to insure each data chunk was located in the most appropriate theme(s). Themes were also validated through a process of transcription inter rater reliability. All participants agreed to participate through a process of informed consent and selected or were assigned pseudonyms to protect their anonymity.

Of the four pre-service teachers, three were male and one was female. At the time of the interviews two were in full time teaching positions, one was substitute teaching, and one was employed at the post-secondary level.

Results

The interview transcripts provided a rich data set relating to the experiences of pre-service teachers in terms of their participation in, and facilitation of the makerspace sessions. This project was purposefully designed to allow pre-services technology education teachers to interact and work with in-service teachers within the context of a makerspace. The project was also designed to empower pre-service teachers with leadership roles in developing and facilitating instruction to intermediate level (grades 7-9) students. As such, pre-services teachers were exposed to various teaching styles and pedagogical approaches throughout their work in facilitating the project. Participants represented their experiential learning as being a highly valuable adjunct to their regular teacher education program. As such, three themes emerged in the data; learning through doing, learning through mentorship, and learning through reflective practice.

Learning through doing

All four pre-service teachers commented on the impact and value of learning through doing. They related these experiences in two sub-themes: technical learning and pedagogical learning. One idea expressed by participants is that for instructional purposes, it is not simply enough to know or be able to learn a skill; teaching it is a whole other matter. This was illustrated by Hermione when she commented that "... you think you know something and then you go to teach it and then you realize how different it is." This emerging realization of the relationship between knowing something and knowing how to teach something is a recurring theme throughout the data and was illustrated again by Samuel when he stated:

... they were learning by doing it, and on top of that we were learning by doing it as well because we were teaching in a different kind of setting. Which is a good thing because we were learning to teach in that kind of setting, so it was experiential for them because they were learning the technical skills that they needed to learn to do what they wanted to do, and it's experiential for us because we were learning the teaching skills that we needed and... ah, improving our technical skills at the same time.

From the quote above the dichotomy of what a teacher knows and what a teacher can do (Gess-Newsome, 2015) is cast within a dual light. Throughout the data the pre-service teachers readily demonstrated an explicit understanding of the importance of not only knowing and understanding conceptual knowledge of the technical and pedagogical, but also the practical and tacit. When viewed from the context of pre-service teacher perceptions the constructionist idea of learning through making and building was a layered experience. Not only were the pre-service teachers making and building to gain their own personal knowledge, they were tasked with facilitating the learning of others as well.

Being responsible for the learning of others through this immersive project allowed the pre-service teachers to quickly develop a sense of their own pedagogical approach through reflective practice. The difference between preconceived notions of teaching and reality were exposed through experience. Michael revealed a preconceived idea about his beliefs about teaching when he said: "... I was thinking I was going to be a teacher, I would just show them how to do it and they will catch on..." This notion was challenged when he realized all his students did not catch on and he had to revise his pedagogy in the moment. The idea of challenging preconceived ideas was a recurring theme throughout the data and is illustrated below when Michael stated:

So, you know, I kind of went and when they needed help, I tried to help them the best way that I thought I might be able to help them, but then after I talked to them the first time I realized what they needed or how they should need the help or be facilitated because they were – I figured out very quickly that they all had different learning styles. And some people caught on the way that I showed it and some people never, so then you had to – I had to go and fix and re-tweak everything that I was saying almost on the spot and make sure that they could understand it to the way that they – their learning experience was.

While there were plenty of opportunities for self-discovery, the inclusion of experienced in-service teachers also supported pre-service student learning. This support and mentorship emerged as a valuable characteristic within the context of this makerspace project.

Learning through mentorships

Makerspaces can bring diverse groups of people with different expertise together (Halverson & Sheridan, 2014; Martin, 2015; Slatter & Howard, 2013). This was the case for this study as three of the pre-service teachers commented on the usefulness of being immersed in an environment that allowed them to interact and observe expert practicing teachers. These interactions and informal mentorship experiences were identified as valuable to the participants' own pedagogical development and validated their personal discoveries of how to interact with intermediate students. Two sub-themes emerged in relation to mentorship: learning through observation and learning through collaboration.

One prominent idea related to pre-service teachers observing, comparing, and modifying their own practice. Michael commented that during the sessions he saw the in-service teachers who worked with us on the project interact with students in multiple ways, but what he focused on was how some of the teachers could adjust their pedagogy to meet the

students at their level. Michael mentioned that it was validating to see that 'one size does not fit all' when he said:

[In-service teachers] would know this [student] worked this way, that one worked this way, so it was good to see that's what I should be doing and following, like them, even though, I should be learning my own way, but it's always good to get steps and pointers.

Picking up strategies through observation and working them into his own pedagogical practice was a valuable aspect of participating in the makerspace project for Michael. Other emergent themes were identified as relationship building and direct collaboration.

The influence of direct collaboration with in-service teachers was noted by Samuel who commented on the supports that were in place when he mentioned he could always ask someone else if he was not sure of something. While Samuel was a facilitator, he realized that his role was fluid in regard to the other participants' collective and individual experiences and expertise. He observed that, "... it's not just learning and a learning experience for the people who come in, we were learning ourselves..." This idea of continually learning from the group was repeated by the other participants when Tony succinctly stated:

So, it's nice to deal with a small group, and also in the setting that we had, there were other teachers around, there were other students, like, my age students that were still learning; new teachers. So, when we had questions or concerns, we could talk to each other, bounce ideas back and forth, and then, you know, if we had no idea, then you know we could go to Mr. G, or you could talk to Mr. S, or Mr. L – whoever was there, and ask them questions and get their opinion and their views.

The idea of open informal collaboration came through at various points in the data analysis suggesting that building working relationships with experienced in-service teachers and other experts increased the confidence and pedagogical ability of pre-services teachers within the context of the makerspace. This type of collaboration was reported by three of the participants as also having helped them navigate their first classroom experiences as new teachers.

Learning through reflective practice

Pre-service teacher reflection on practice has been noted as a key area for developing pedagogical awareness (Banks et al., 2004). As the makerspace project was designed to allow iterations of instruction for pre-service teachers, there were opportunities for them to reflect and change their practice. The data revealed that all pre-service teachers reflected, refined, and redefined their pedagogical practices either through self-reflection and/or the influence of student feedback.

All participants acknowledged the difficulty in preparing and teaching or facilitating a lesson to a group of students, who were not known to them. This was apparent when Hermione and Samuel commented on how they felt the first time facilitating their lessons. Both asserted that the first time through was a learning experience and in particular Hermione felt like she was "... kind of like making it up as I go..." But through the process of teaching and facilitating their lessons multiple times their confidence level increased and there was a

growing sense of fluidity in interacting with the students. Mistakes were also mentioned as points of reflective learning. Reflecting on, and correcting perceived mistakes were identified as a way of modifying practice in a positive manner. While these experiences were expressed as reflection post instruction, another theme emerged in the data that had an impact on pre-service pedagogical practice in a much more immediate way, direct student feedback.

Two of the participating pre-service teachers commented on the influence direct student feedback had on their immediate pedagogical practice. This feedback guided their teaching in an inductive and emergent fashion based on the immediate needs of the students they were engaged with. There was a sense from the pre-service teachers that not being in-tune with direct student feedback was an issue in their facilitation. This was illustrated when Samuel stated:

I like to get feedback first. So, you know, I'm working with people on the computer program side where we were doing the *SketchUp*, and I asked them, you know, "What do you want to make?" I'm not, you know, I'm going to... show them an example myself, keep it quick, right, because they want to get to what they want to do, right.

Both Michael and Samuel conveyed the idea that their task was to help the intermediate students understand the concepts and material required to complete the task and modifying their approach was key to their success as a teacher. As such, the iterative nature of the project allowed them to fine tune their pedagogical approach.

Conclusion

While the idea of hands-on learning and making is nothing new in formal public education it is interesting to note that its latest iteration, under the moniker of makerspace, provides opportunities for renewed discussion of its potential worth. From the context of this study we were interested in understanding if makerspaces could be utilized for pre-service teacher education. In particular, we were interested in how pre-service teachers represent the value of co-curricular experiential learning opportunities (makerspaces) in shaping their learning and pedagogical practices. From an analysis and discussion of the data it would appear that pre-service teachers do value such experiences for a variety of reasons. Three main ideas emerged as lending value to the pre-service teachers' experiences. First, the opportunity to develop both technical and pedagogical knowledge and skills through doing was highlighted in the data as being highly valuable to the pre-service teachers. Second, the opportunity to develop relationships and collaborate with current in-service teachers emerged as a valuable experience. Third, reflecting and refining pedagogical practice through their leadership roles in the makerspace was also valued. While it has been proposed that makerspaces may have potential as good learning environments for students (Cohen et al., 2017; Halverson & Sheridan, 2014; Hsu, Baldwin, & Ching, 2017; Martin, 2015), this research would suggest that they may also make for good pre-service teacher experiential learning as well.

References

- 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. <https://doi.org/10.1023/B:ITDE.0000026475.55323.01>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Chambers, D., & Lavery, S. (2012). Service-Learning: A Valuable Component of Pre-Service Teacher Education. *Australian Journal of Teacher Education*, 37(4). <https://doi.org/10.14221/ajte.2012v37n4.2>
- Cohen, J., Jones, W. M., Smith, S., & Calandra, B. (2017). Makification: Towards a Framework for Leveraging the Maker Movement in Formal Education. *Journal of Educational Multimedia and Hypermedia*, 26(3), 217–229.
- Dewey, J. (1916). *Democracy and Education: An Introduction to the Philosophy of Education*. Retrieved from <http://archive.org/details/democracyandedu00dewegoog>
- Gao, X. (2015). Promoting experiential learning in pre-service teacher education. *Journal of Education for Teaching*, 41(4), 435–438. <https://doi.org/10.1080/02607476.2015.1080424>
- Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK. In P. Friedrichsen, J. Loughran, & A. Berry (Eds.), *Re-examining pedagogical content knowledge in science education* (pp. 28–42). London: Routledge.
- Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, 84(4), 495–504.
- Hildenbrand, S. M., & Schultz, S. M. (2015). Implementing Service Learning in Pre-Service Teacher Coursework. *Journal of Experiential Education*, 38(3), 262–279. <https://doi.org/10.1177/1053825915571748>
- Hsu, Y.-C., Baldwin, S., & Ching, Y.-H. (2017). Learning through Making and Maker Education. *TechTrends*. <https://doi.org/10.1007/s11528-017-0172-6>
- Kafai, Y. B., & Resnick, M. (2012). *Constructionism in Practice: Designing, Thinking, and Learning in A Digital World*. Routledge.
- Kang, D. Y., & Martin, S. N. (2018). Improving learning opportunities for special education needs (SEN) students by engaging pre-service science teachers in an informal experiential learning course. *Asia Pacific Journal of Education*, 38(3), 319–347. <https://doi.org/10.1080/02188791.2018.1505599>
- Kolb, D. A. (2014). *Experiential Learning: Experience as the Source of Learning and Development*. FT Press.

Kurti, R. S., Kurti, D. L., & Fleming, L. (2014). The philosophy of educational makerspaces part 1 of making an educational makerspace. *Teacher Librarian*, 41(5), 8.

Martin, L. (2015). The promise of the Maker Movement for education. *Journal of Pre-College Engineering Education Research (J-PEER)*, 5(1), 4.

McWilliam, E. (2009). Teaching for creativity: from sage to guide to meddler. *Asia Pacific Journal of Education*, 29(3), 281–293. <https://doi.org/10.1080/02188790903092787>

Moon, J. A. (2004). *A handbook of reflective and experiential learning: theory and practice*. London New York: RoutledgeFalmer.

Papert, S., & Harel, I. (1991). Situating constructionism. In S. Papert & I. Harel (Eds.), *Constructionism* (pp. 1–14). Hillsdale, NJ: Lawrence Erlbaum Associates.

Slatter, D., & Howard, Z. (2013). A place to make, hack, and learn: makerspaces in Australian public libraries. *The Australian Library Journal*, 62(4), 272–284. <https://doi.org/10.1080/00049670.2013.853335>

Vygotsky, L. (1962). *Thought and language*. <https://doi.org/10.1037/111193-000>

Laying down the “T” and “E” in STEM education: Design as the basis of an integrated STEM philosophy.

Jonas Hallström, Piet Ankiewicz



Jonas Hallström
Linköping University
Sweden
jonas.hallstrom@liu.se



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

ABSTRACT

STEM – science, technology, engineering, and mathematics – has become ubiquitous in education. How STEM and STEM education are to be defined is still a matter of debate, however, and it is only just recently that STEM education has been probed from a philosophical point of view. The need for a philosophical basis for STEM education is therefore fundamental. The aim of this study is thus to investigate specifically the role of the “T” and “E” in STEM, and how they not only may be fruitfully integrated with the “S” and “M”, as part of a philosophy of STEM education, but also potentially form a methodological backbone of such a philosophy when it comes to design. The research question that underpinned the study is: What are the affordances of Mitcham’s (1994) fourfold philosophical framework of technology for unifying the STEM subjects, with particular consideration of the “T” and “E”? The research methodology consisted of a qualitative meta-synthesis of the literature regarding the philosophy of technology and engineering, technology education, and the current issues of integrating the various STEM subjects. We conclude that from a methodological point of view – Mitcham’s “activity” – the design in technology (“T”) and engineering (“E”) holds the most promising affordances for unifying the four STEM subjects. Design as part of particular design projects may require the “design” of applicable scientific experiments as well as the design of applicable mathematics expressions and formulae specifically when modelling in “E” (and “T”).

Keywords: technology education; engineering education; STEM education; design; philosophy

Introduction

In the last decade the acronym STEM – science, technology, engineering, and mathematics – has become a buzzword, typically invoked when discussing educational policy, curricula and economic competitiveness. The acronym has also become ubiquitous in education, in particular in relation to educational initiatives in science and engineering education broadly defined. STEM as an educational enterprise has been growing in importance, particularly in the USA, UK, and other Anglo-Saxon countries (e.g. Banks & Barlex, 2014). How STEM education is to be defined is still a matter of debate, however. It is only just recently that STEM education has been probed from a philosophical point of view, with the aim of investigating what it is and what underpins it theoretically, although it is often from the point of view of one of the subjects such as science or mathematics (see e.g. Chesky & Wolfmeyer, 2015).

The need for a philosophical basis for *all* of STEM education is therefore fundamental, so that educational initiatives can rest on a solid philosophical foundation. Arguments have been put forward for a completely subject-based STEM education, that is, an S.T.E.M. education (e.g. Henderson et al., 2017), but various integrated approaches seem to dominate (e.g. Kelley & Knowles, 2016; Peterman et al., 2017). Criticism against various cooperative STEM approaches has also been put forward and includes, for example, that they may lead to a conflation of science and technology, or that the “T” and the “E” often tend to be downplayed in favour of the “S” and the “M” (e.g. Bers et al., 2013; Sanders, 2009). There is thus a philosophical vagueness surrounding the concept of STEM education. Pitt (2009) summarises it in the following way:

Some people define any activity that involves any of science, technology, engineering or mathematics as a STEM activity; others argue that intrinsic to the concept is some linking of two or more of the component areas of learning, and that real STEM must be more than the sum of its parts (Pitt, 2009, p. 41).

The root of this ambiguity arises from the fact that science, technology, engineering and mathematics as subjects are not necessarily connected in neither content nor pedagogy. Tang and Williams (2018) tested the concept of an integrated STEM literacy empirically, and concluded that:

Based on the similarities found in several language and thought processes of the disciplines, we conclude that there is presently a research basis for postulating a unitary STEM literacy that reflects the shared general capabilities required in all the STEM disciplines. At the same time, there are also substantial differences that support the retention of the existing literacy constructs (i.e., S.T.E.M. literacies) to reflect the specific linguistic, cognitive and epistemic requirements found in each disciplinary area. This distinction from the singular STEM literacy is necessary to highlight the skills and practices that are unique to each particular discipline, and therefore not applicable in all the other disciplines (p. 1).

Therefore, a great challenge for teachers in STEM subjects is to design classroom activities and lessons that integrate two or more of the subjects in their teaching in both a meaningful and relevant way (Bell, 2016; De Vries, 2017a; Margot & Kettler, 2019; Radloff & Guzey, 2016). Thus, it may be possible to balance the intrinsic, epistemic qualities of each subject

with cooperation concerning the common general capabilities, that is, S.T.E.M. literacies with STEM literacy.

If STEM education is to remain philosophically solid and powerful as an educational endeavour it is clear that it should revolve around some kind of integration of two or more of the four subjects, at the same time as the core of each subject has to be respected. The aim of this study is thus to investigate specifically the role of the “T” and “E” in STEM, and how they not only may be fruitfully integrated with the “S” and “M”, as part of a philosophy of STEM education, but also potentially form a methodological backbone of such a philosophy when it comes to *design*. Design is here defined as an activity aimed at achieving the goals of people, companies or society more broadly, by describing objects or systems that are able to fulfil technical functions efficiently (Vermaas et al., 2011). The research question that underpinned the study is: What are the affordances of Mitcham’s (1994) fourfold philosophical framework of technology for unifying the STEM subjects, with particular consideration of the “T” and “E”? The research methodology for this philosophical paper consisted of a qualitative meta-synthesis of the literature regarding the philosophy of technology and engineering, technology education, and the current issues of integrating the various STEM subjects.

A philosophical framework for technology, technology education – and STEM education

According to Mitcham’s (1994) fourfold philosophical framework, technology is manifested as object, knowledge, activity and volition. Technological knowledge and volition, with their origin within human beings, give rise to technological activities expressed as concrete technological objects. These four modes of manifestation of technology have been linked to the four components of general philosophy, as well as to the analytical tradition within the philosophy of technology, namely ontology, epistemology, methodology and volition respectively (Ankiewicz, 2016, 2019; Ankiewicz et al., 2006; De Vries, 2017b), as illustrated in Fig. 1. On the one hand, technological knowledge and volition, with their origin within human beings, give rise to technological activities expressed as concrete technological objects (indicated by the black arrows). On the other hand, objects can also influence peoples’ activities, knowledge and their will (indicated by the grey arrows).

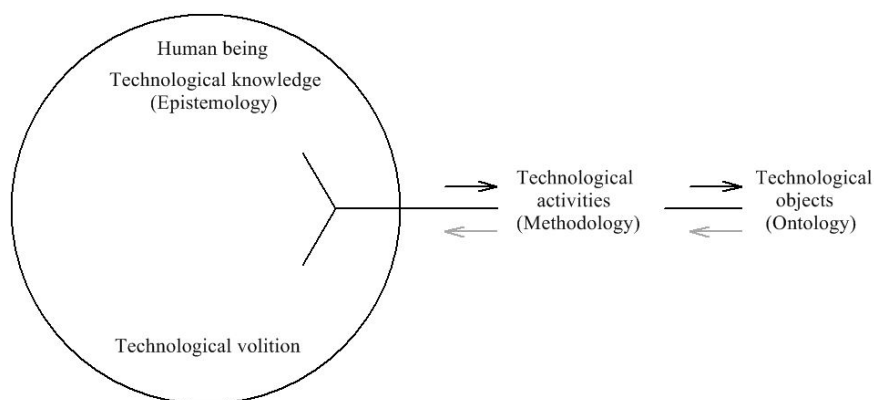


Figure 1: Modes in which technology is manifested (Mitcham, 1994, pp. 160 and 209, as adapted by Ankiewicz, 2019 and Ankiewicz, De Swardt and De Vries, 2006).

It follows that all of these four components of philosophy could be applied also to the “S”, “E” and “M” in a STEM education philosophy, although it remains to be seen whether they can be cogently unified philosophically. Evidence from other studies suggests that the STEM subjects are too dissimilar concerning ontology and epistemology for a successful integration on these grounds (e.g. Tang & Williams, 2018), so we suggest *methodology* as an area to explore philosophically across the STEM subjects, with special regard to the primary methodology of technology education – design. We thus need to find common ground for a transdisciplinary STEM philosophy built on interaction and cooperation – looking sideways, whilst respecting the integrity of each subject – in precisely the methodological dimension.

Design methodology as a way of philosophically unifying the STEM subjects

Design processes are the object studied in the discipline of design methodology (De Vries, 2001). Two radically different paradigms form the basis of the discipline of design methodology, i.e. the rational problem-solving and the reflective practice paradigm. The rational problem-solving approach is a more structured approach generally associated with engineers while the reflective practice paradigm is a less structured approach usually associated with architects (Ammon, 2017; Ankiewicz et al., 2006; Dorst, 1997). A combination of the two approaches into the conceptual, information and embodiment stages of design activity results in a dual model of design methodology (Dorst, 1997).

Design is the primary methodology of technology which is more intuitive (De Vries, 2018) as it has an element of trial and error to it (Williams, 2011) and is in itself “an independent epistemic praxis” (Ammon, 2017, p. 495); thus, it is largely associated with the reflective practice paradigm. Design also features in engineering which is part of the broader field technology (De Vries, 2018). Engineering is actually a sub-set of the broad area of technology (Williams, 2011). However, design as a characteristic of engineering is different from design in technology. It is infused with the more structured elements of modelling, quantification and the use of concepts (De Vries, 2018); thus it is generally associated with the rational problem-solving paradigm.

Based on Dorst’s (1997) dual model the combination of “T” and “E” could provide a clue for the problem on how to exploit the affordances of STEM (De Vries, 2018). Like other scholars (e.g. Williams, 2011) we do not support an integrative approach to STEM for the mere sake of integrating the STEM subjects. We acknowledge the dangers of integration for the integrity of the various STEM subjects; there must be a relevant, authentic connection between the STEM subjects (De Vries, 2018).

There are particular knowledge aspects in science and mathematics (as well as other subjects) supporting technology that do not belong to technology. Hence the – perhaps somewhat arrogant – statement: “Technology [...] is a field of study that has its own intellectual domain; yet, it can make maths, science, and other fields tangible and relevant to bring them to life” (ITEA, 1997, p. ii). Therefore, it is not really such a novel idea that technology (“T”) can be the “integrator” of “S”, “E” and “M” (Ankiewicz, 2003; Bybee, 2013; Ritz & Fan, 2015). Bishop (1988) also concedes the primacy of technology, and mathematics, in this sense, as a cultural product or tool.

From the literature on STEM education there seems to be mainly two ways of interaction, i.e. the application of existing knowledge from the STEM subjects (e.g. Barlex, 2007) and an approach where there is knowledge development in all STEM subjects simultaneously, as well as the application of knowledge from the various STEM subjects (De Vries, 2018). Focusing on design – as a characteristic of both technology and engineering – may be conducive to the application of existing knowledge from the STEM subjects as well as knowledge development in all STEM subjects simultaneously.

Barlex (2007) mentions a more incidental type of interaction between the STEM subjects which occurs in design projects when technology students apply knowledge from the other STEM subjects (Williams, 2011). As opposed to incidental interaction between the STEM subjects – and in order to establish a real connection between them – De Vries (2018) suggests the use of particular design challenges in which engineering principles, scientific concepts and mathematical ways of thinking are essential for finding solutions to the challenge. Thus, he advocates an approach where there is knowledge development in all STEM subjects simultaneously, and not merely the application of existing knowledge related to them – similar to how it happens in practice. In such design challenges students will “design” and do experiments to understand scientific phenomena. Design in science may also be more experimentally oriented – such as, for example, in synthetic chemistry – whereas design in technology and engineering are not really experiments in the scientific sense but rather an epistemic practice of its own that is open ended, iterative and produces its own knowledge (Ammon, 2017). Design in technology, engineering – and even sometimes in mathematics, according to Bishop (1988) – will typically lead to the making of an object, or system (cf. Vermaas, 2011). The students will also “design” mathematical expressions or functions and do calculations to optimise their design by modelling to test their optimisations. The steps of mathematical modelling resemble, to a large extent, the stages of technological design within the rational problem solving paradigm. Such challenges will fit the nature of design as a process, and in the philosophical sense a methodology, in which both new knowledge is developed (about designing itself, but also science and engineering), and existing knowledge (previously learnt in science, technology and/or mathematics) is applied (De Vries, 2018; Vossen et al., 2019).

Concluding discussion

Philosophy – more specifically Mitcham’s (1994) fourfold philosophical framework of technology – holds affordances for cogently unifying the STEM subjects. From an “S” and “M” perspective there is philosophically – specifically ontologically and epistemologically – little substantially in common with “T” and “E” that could unify the four STEM subjects, although, for instance, Bishop (1988) argues that mathematics is basically to be seen as a technology, and specifically expounds on a conception of design similar to in technology and engineering. Nevertheless, “S” and “M” can actually advance independently of “T” and “E”. However, from a methodological point of view the “design” in “T” and “E” holds the most promising affordances for unifying the four STEM subjects, especially when considering that design in mathematics in certain conceptions also aligns with this. Design as part of particular design projects may require the “design” of applicable scientific experiments as well as the design of applicable mathematics expressions and formulae specifically when modelling in “E” (and “T”). As “T” and “E” are indispensable for STEM, we would not have had STEM if it was not for the “T” and

“E”. We will expand this study in the near future indicating that the fourth component of philosophy, i.e. volition, may hold additional affordances for coherently unifying the four STEM subjects.

Finally, we call for more research about design in STEM classrooms. It is imperative that interventions are carried out which integrate the STEM subjects in authentic design projects in a similar manner to those described by De Vries (2018), in which technological and engineering principles, scientific concepts and mathematical ways of thinking are essential for finding solutions to the challenges in the projects. Furthermore, such research should consider the ways the separate STEM subjects interact around a design challenge, and how students could benefit by engaging in design as a methodology in all four subjects. Models and modelling could, for example, be one way of methodologically creating bridges between the STEM subjects in such authentic design projects (cf. Hallström & Schönborn, 2019).

Acknowledgement

We would like to express our sincere gratitude to Dr Francois van As for his assistance with the graphics in the paper.

References

- Ammon, S. (2017). Why designing is not experimenting: Design methods, epistemic praxis and strategies of knowledge acquisition in architecture. *Philosophy & Technology*, 30, 495-520. doi: 10.1007/s13347-017-0256-4
- Ankiewicz, P. (2003). Technology education at school: Illusion or reality? *Inaugural address*. Rand Afrikaanse Universiteit, Johannesburg.
- Ankiewicz, P. (2016). The relevance of indigenous technology knowledge systems (ITKS) for the 21st century classroom. *In PATT 32 conference proceedings*, (pp. 22-34). Utrecht, The Netherlands.
- Ankiewicz, P. (2019). Alignment of the traditional approach to perceptions and attitudes with Mitcham’s philosophical framework of technology. *International Journal of Technology and Design Education*, 29(2), 329-340. <https://doi.org/10.1007/s10798-018-9443-6>
- Ankiewicz, P., De Swardt, 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
- Banks, F. & Barlex, D. (2014). *Teaching STEM in the secondary school: Helping teachers meet the challenge*. London: Routledge.
- Barlex, D. (2007) Capitalising on the utility embedded in design & technology activity: An exploration of cross-curricular links. In Dr. E.W.L., Norman and D., Spendlove (Eds.)

- Linking learning*, The Design and Technology Association Education and International Research Conference 2007, 5 – 10, Wellesbourne, Design & Technology Association.
- 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.
- Bers, M., Seddighin, S., & Sullivan, A. (2013). Ready for robotics: Bringing together the T and E of STEM in early childhood teacher education. *Journal of Technology and Teacher Education*, 21(3), 355-377.
- Bishop, A.J. (1988). Mathematics education in its cultural context. *Educational Studies in Mathematics*, 19(2), 179-192.
- Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. Arlington: NSTA Press.
- Chesky, N.Z. & Wolfmeyer, M.R. (2015). *Philosophy of STEM Education: A critical investigation*. New York: Palgrave MacMillan.
- 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. (2017a). Technology education: An international history. In M.J. de Vries (Ed.), *Handbook of Technology Education*. Dordrecht: Springer.
- De Vries, M.J. (2017b). Philosophy as critique. In Williams, P.J., & Stables, K. (Eds.), *Critique in design and technology education*. Dordrecht, NL: Springer, DOI 10.1007/978-981-10-3106-9
- De Vries, M.J. (2018). The T and E in STEM: From promise to practice. In M.J. de Vries, S. Fletcher, S. Kruse, P. Labudee, M. Lang, I. Mammes, C. Max, D. Münk, B. Nicholl, J. Strobel, & M. Winterbottom (Eds.) *Research in technology education*, 11-19. Waxmann.
- Dorst, K. (1997). *Describing design*. PhD thesis, Technische Universiteit Delft, Delft.
- Hallström, J. & Schönborn, K. (2019). Models and Modelling for Authentic STEM Education (submitted).
- Henderson, C., Connolly, M., Dolan, E.L., Finkelstein, N., Franklin, S., Malcom, S., Rasmussen, C., Redd, K. & St. John, K. (2017). Towards the STEM DBER alliance: Why we need a discipline-based STEM education research community. *International Journal of STEM Education*, 4(14), 1-4.
- International Technology Education Association (ITEA), (1997). *Standards for technology education. First draft*. Blacksburg, Va: Virginia Tech.
- Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, 3(1), 11.
- Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, 6(2), 1-16.

- Mitcham, C. (1994). *Thinking through Technology*. Chicago: The University of Chicago Press.
- Peterman, K., Daugherty, J. L., Custer, R. L., & Ross, J. M. (2017). Analysing the integration of engineering in science lessons with the Engineering-Infused Lesson Rubric. *International Journal of Science Education*, 39(14), 1913-1931.
- Pitt, J. (2009). Blurring the Boundaries – STEM education and education for sustainable development. *Design and Technology Education: An International Journal*, 14(1), 37-48.
- Radloff, J. & Guzey, S. (2016). Investigating preservice STEM teacher conceptions of STEM Education. *Journal of Science Education & Technology*, 25, 759-774.
- Ritz, J. M., & Fan, S. C. (2015). STEM and technology education: International state-of-the-art. *International Journal of Technology and Design Education*, 25(4), 429-451.
- Sanders, M. (2009). STEM, STEM Education, STEMmania. *The Technology Teacher*, December/January, 20-26.
- Tang, K.-S. & Williams, P.J. (2018). STEM literacy or literacies? Examining the empirical basis of these constructs. *Review of Education*, DOI: 10.1002/rev3.3162.
- Vermaas, P., Kroes, P., van de Poel, I., Franssen, M., & Houkes, W. (2011). *A Philosophy of Technology: From Technical Artefacts to Sociotechnical Systems*. San Rafael, CA: Morgan & Claypool Publishers.
- Vossen, T. E., Henze, I., De Vries, M. J., & Van Driel, J. H. (2019). Finding the connection between research and design: the knowledge development of STEM teachers in a professional learning community. *International Journal of Technology and Design Education*, 1-26.
- Williams, P. J. (2011). STEM education: Proceed with caution. *Design and Technology Education: An International Journal*, 16(1), 26–35.

Teachers' attitudes towards teaching programming in Swedish Technology education.

Eva Hartell, Andrew Doyle, Lena Gumaelius



Eva Hartell
KTH Royal Institute
of Technology
Sweden
ehartell@kth.se



Andrew Doyle
KTH Royal Institute
of Technology
Sweden
adoyle@kth.se



Lena Gumaelius
KTH Royal Institute of
Technology
Sweden
lenagu@kth.se

ABSTRACT

Programming was introduced as a core-content in the Swedish national curriculum during a 2018 revision. The introduction of programming as part of Technology and Mathematics has been surrounded with a lot of questions of how, when, what and by whom programming should be taught. It is acknowledged that teachers do not often have the content expertise or confidence in teaching 'new' topics as they are assigned to curricula. Previous research has explored this through the lens of teacher self-efficacy, where results have indicated that teachers' self-efficacy in a particular area is important for creating effective learning opportunities for pupils in school.

This paper reports on preliminary findings from an on-going project focusing on teacher self-efficacy in relation to the introduction of programming to the primary Technology curriculum. The projects' objectives were to increase teachers' self-efficacy to teach programming in the Technology subject, and as a result of this, increase learning opportunities for the pupils.

In order to be able to measure teachers' development of self-efficacy towards teaching primary programming an instrument was developed based on an existing instrument used for measuring self-efficacy for science teaching. The Dimensions of Attitudes towards Programming (DAP) instrument was designed and piloted in two schools. The preliminary findings show that the DAP-instrument fulfilled its purpose within this project but needs to be further validated to become a valid instrument to measure teachers' self-efficacy in programming in a broader sense. Two themes identified from the analysis are discussed in this paper; (1) a lack of confidence in teaching programming, which appeared to ultimately result in, (2) teachers' questioning the why behind teaching programming in the Swedish primary school.

Keywords: programming, self-efficacy, Technology education, primary education

Introduction

Technology subject is mandatory for all students from year 1–9 in Sweden. Technology should be taught according to national syllabus and there is allocated instructional time of 200 hrs. Very few teachers have subject specific teacher education in Technology and pupils are often taught by their class teacher in primary years.

Technology is a mandatory subject in the Swedish compulsory school. Programming was introduced as part of the core content of the national Technology syllabus with the revision of the national curriculum (LGR11), which came into effect on the 1st July 2018 i.e. from the autumn term 2018 (Statens Skolverk, 2018). The introduction of programming as part of the Technology subject has been surrounded by many questions and considerations such as the content of programming and how it should be taught.

This paper reports preliminary findings from a project Tillit till IT i programmeringsundervisning (*Self-efficacy in teaching primary programming*) undertaken in two primary schools during fall 2018. This project emerged from discussions held during spring 2017 among teachers, school management and researchers. They discussed the situation for teaching Technology based on an implemented municipal-wide review and also the planned introduction of programming into Swedish compulsory school.

The overall purpose of the Tillit till IT project was for teachers to develop knowledge and self-efficacy in their ability to teach primary Technology education, particularly the core content associated with programming and to utilize, translate/transform and develop subject didactics for pupils. A total of five classes (n=125) of Year 3 (9-year-olds) participated in the project together with their teachers.

The expected outcomes of this project were (in no particular order):

- Increase teaching in programming in grades 1-3;
- Increase teachers' self-efficacy to teach pupils with reading and writing difficulties in general and specifically in programming;
- Produce concrete teaching examples, including pupil examples, of programming.

The Tillit till IT project had a particular focus on teaching programming to pupils with reading and writing difficulties in year 3. This particular focus stems from the preceding discussion with teachers, where concerns on how the teaching of programming would affect and be influenced by pupils who experience different forms of challenge in terms of reading and writing, as programming was often associated with code writing. Based on those concerns the project manager applied and received funding from *The National Agency for Special Needs Education and Schools* in Sweden. However, this is outside the scope of this paper and will be the subject of a future paper

Parallel to the Tillit till IT project, the two schools had also been offered to participate in municipality wide CPD course including review of curriculum and practical teaching and learning activities focusing digitalisation and programming. This initiative comprised of three – three hour-long workshops held in the municipality.

About self-efficacy and teaching

Previous research has shown that teachers' self-efficacy is of great importance when considering student learning opportunities as it has been shown to influence teachers' selection of content (Bandura, 1997; Eells, 2011; Nilsson, 2008; Rohaan, Taconis, & Jochems, 2012). This relationship to specific content and context makes self-efficacy difficult to measure, as the construct needs to be situated within a specific curricular context. This relationship is

further complicated in Swedish Technology education, as the curriculum is broad and evidence has shown that teachers' can perceive and in turn enacted the subject in very different ways (Fahrman, Norström, Gumaelius, & Skogh, 2019).

Research question

The goal of the school development initiative was to investigate Technology teachers' self-efficacy in the teaching of programming. Based on previous literature (Bandura, 2000; Palmer, Dixon, & Archer, 2015; Hattie, 2016; Hartell, 2018) that has found that self-efficacy affects the amount of teaching of a particular content within a domain, the researchers focused on teacher self-efficacy in programming by investigating levels of perceived self-efficacy among the participants in the initiative.

The following research question was formulated:

- What dimensions of attitudes towards programming (cognition, affect and perceived control) do teachers express when faced with the introduction of programming in primary Technology education?

Measuring dimensions of attitudes towards teaching programming

Teachers' attitudes towards teaching are recognised as being highly contextual and therefore difficult to measure. However, to investigate teachers' attitudes towards teaching programming within this project an instrument to measure teachers' attitudes towards teaching primary programming was needed. A literature review was undertaken in order to find an existing instrument, however, no sufficient instrument was identified. Therefore this project took an exploratory approach by transforming an existing instrument designed to measure teachers' attitudes in science education and contextualised it into primary programming. The instrument was named *Dimensions of Attitudes towards Programming* (DAP).

The preceding instrument that DAP is based upon is called Dimensions of Attitudes towards Science (DAS) and is designed by a Dutch research group led by van Aalderen-Smeets. The DAS scale is based on the theoretical framework of van Aalderen-Smeets et al. (2012). The reliability and validity analyses were carried out by van Aalderen-Smeets & van der Molen (2013). The framework (Figure 1) consists of three dimensions (Cognition, Affect, and Perceived Control) accommodating seven components that represent different thoughts, beliefs and/or feelings towards teaching science.

Cognitive beliefs refer to teachers' beliefs and opinions about (a) the relevance of science and science education, (b) beliefs about the relative difficulty of (teaching) science, and (c) gender stereotypical beliefs regarding science and science teaching. The second dimension of affect contains the independent subcomponents of (a) enjoying (teaching) science and (b) anxiety related to (teaching) science. The third dimension, perceived control, refers to the amount of control teachers perceive to have over (teaching) science and it consists of (a) self-efficacy (an internal sense of control, such as the perceived capacity to teach science) and (b) perceived dependency on context factors (beliefs about the extent to which you feel dependent on external factors to teach science, such as the availability of teaching-methods or materials, enough time, or other resources).

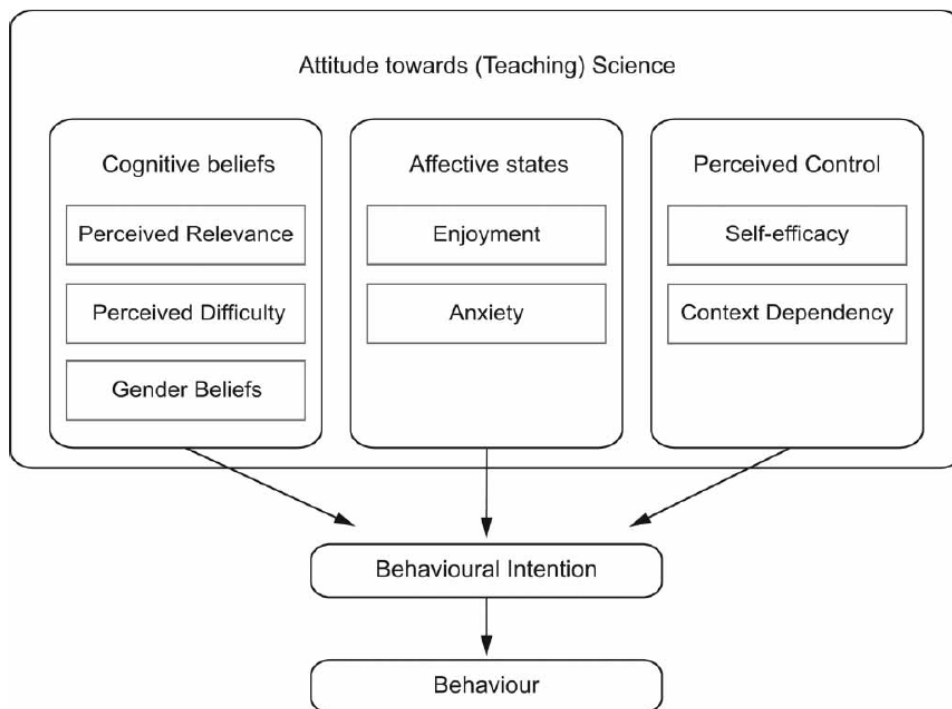


Figure 17. Theoretical framework for the construct of primary teachers' attitudes toward (the teaching of) science (van Aalderen-Smeets et al., 2012)

In the view of van Aalderen-Smeets and van der Molen (2015), the perception of teachers regarding their dependency on contextual factors (e.g., their belief that they can teach science only if their school ensures the availability of the proper materials or sufficient preparation time) is an indispensable component of a complete theoretical framework of primary teachers' attitudes toward science. For a more complete description of the theoretical framework, refer to van Aalderen-Smeets et al. (2012).

Development of DAP

DAP is a development of an already existing instrument measuring attitudes in science education; *the Dimensions of Attitudes towards Science* education (DAS) instrument constructed by the Dutch team (van Aalderen-Smeets et al., 2012).

Two alterations were made to the scale prior to pilot implementation. Firstly, a professional translator was commissioned to translate the DAS instrument into Swedish. The translations were then proof read by members of the research team. This translation was commissioned so that teachers' may better access the scale in their native language. Secondly, the use of the term "science" in the scale was replaced with the term "programming" (Swedish for programming). Due to the context dependent nature of self-efficacy beliefs the DAP instrument was complemented with five questions from the estimation instrument LIKA. The LIKA instrument is commissioned by the employers' organisation Swedish Association of Local Regions and Authorities (SALAR) to facilitate the digitalization of schools and preschools. The LIKA instrument is designed as a measurement instrument to help schools to measure their ICT-maturity and help them stay focused when implementing digitalisation (SALAR, 2018). It consists of different sections focusing on e.g. leadership, infrastructure, professional development and use of digital tools. The questions directly focused on core content of programming were added to the DAP instrument, in order to develop deeper insight on the Swedish school context.

As a result of these amendments, the survey consisted of 33 items (28 DAP, followed by 5 LIKA, and then an open question to comment on the survey). The items were scored on a 1–5 Likert scale (1 = strongly disagree and 5 = strongly agree).

Methodology

The DAP instrument was piloted with teachers from two primary schools. A total of 21 respondents completed the pilot survey, which corresponds to a response rate of approximately 80%. Their teaching experience ranges from recently graduated to 25 years of experience (mean about 12 years). As a group they have a higher degree of teacher education degree compared to the rest of the municipality and country and five of them mention that they have a certificate in Technology. The subject they prefer to teach most is Swedish followed by Social sciences. Two of them mention Technology as one of their favourite subjects to teach.

To support the findings from the survey, a number of classroom observations and semi-structured interviews were undertaken with participating teachers. The data conducted through these means were analysed using the thematic analysis protocol advocated by Braun and Clarke (2006).

Results and discussion

The following section provides an overview of the findings from the thematic analysis of field notes, supported by the findings from the DAP instrument presented in table 1. Two themes were identified from the analysis that will be discussed in this paper; (1) a lack of confidence in teaching programming, which appeared to ultimately result in, (2) teachers' questioning the why behind teaching programming in the Swedish primary school.

Despite programming having been present in curriculum for a full term, and having engaged with the school development initiative, teachers' self-efficacy in teaching programming varied significantly (Table 1). The variances in self-efficacy were reflected in the classroom observations and interviews with teachers, where their reliance on pre-existing materials developed to assist in teaching programming were observed. It emerged through the interviews that a large factor influencing this pedagogical decision was a lack of experience in teaching the topic before. This was found to be a common problem across subjects with the exception of teachers' that have previously engaged with teaching the topic.

Rather interestingly and in contrast to this however, teachers did perceive programming as a general topic as something relevant for pupils to engage with in their primary education.

Table 1 Overview of DAP survey data

	Cognitive beliefs			Affective states		Perceived Control	
	Perceived Relevance	Gender	Perceived Difficulty	Enjoyment	Anxiety	Self-efficacy	Context Dependency
strongly disagree	1%	81%	2%	10%	43%	31%	18%
	9%	12%	12%	15%	10%	15%	10%
	23%	3%	50%	34%	31%	29%	22%
	22%	3%	33%	23%	9%	17%	35%
strongly agree	45%	1%	3%	19%	8%	8%	15%

Further to this, it was observed that the variances in self-efficacy had minimal impact on teachers' enjoyment in teaching programming. The main reasons behind this appeared to be pupils' perceptions of programming as being *unique* and very different from *normal practices* in school.

The second theme that was identified in the thematic analysis was teachers' questioning behind the why of teaching programming in the Swedish primary curriculum. This may appear at first counterintuitive given the results identifying high levels of agreement on the relevance, where 45 % strongly agreed that programming is relevant to teach. However, their self-efficacy varied significantly. This suggests that although the teachers recognised the importance of teaching programming, and they were not anxious in teaching, they were not confident in their teaching either. This theme was also evident with teachers that have previously taught programming (n=15), suggesting that it may not be a threshold concept that comes with experience. Teachers questioning of the addition of programming appeared to centre on the unique contribution of programming within an already crowded curriculum.

Central to this discussion was the use of specific resources for teaching programming. Without the critical discussion surrounding why engagement is mandated with specific topics (and resources) in the classroom, teachers are left in a space where they must implement a tool without understanding the fundamental principles associated with programming. As a result of this, teachers expressed pressures to do programming, often in spaces where they themselves do not understand the fundamentals of the subject area, thus resulting in questions of the why behind having to teach programming.

Programming is surrounded with many challenges. Not only in terms of teachers own knowledge and skills but also in terms of tools and equipment. Access to learning opportunities for teachers as well as equipment is needed. The following comment from the survey summarises this concern;

“What becomes difficult with working with programming is that the material that is available at the school is not up to date and that we have too little laboratory equipment /material for the pupils to delve into perhaps facilitate understanding with the programming. We have had a CPD education at X-CPDCompany, but we cannot use the things we have learned there because we have old iPads and no laboratory/practical equipment/material.”

Teacher 2

The interview data suggests that teacher activity is largely related to writing instructions, without the use of programming equipment. The fact that Swedish is their preferred subject to teach may play a role; however in itself is not a sufficient explanation. Activities that need equipment where the pupils use different digital tools to support the work with drawings and constructions are surprisingly few. A plausible explanation supported by the quote above is that pupils are not taught that much due to the lack of equipment. This can be contextualised even more by going back to Hartell (2013), which described Technology teachers' classroom assessment practices, and showed that teachers at their own expense cover lack of equipment by bringing stuff from home. Back then it was not digital tools, which perhaps made it easier to compensate using private means.

Conclusions and future directions

In order to measure teachers' self-efficacy in teaching programming an instrument was needed. No existing instrument was found, hence we needed to design our own (DAP). We did that by transforming an existing instrument focusing on science education (DAS) into an instrument focusing on programming and adding five items (LIKA) to put it into context. Piloting

the instrument in two schools showed the DAP to be a useable instrument for measuring teachers' self-efficacy in teaching primary programming.

The development and implementation of the DAP instrument for wider use is still in its infancy. Its use in this paper was primarily to probe into teachers' attitudes towards teaching programming. Future work will focus on ascertaining the construct validity of the instrument with a larger sample as the project is now being scaled up to investigate the predictive validity of the instrument with a larger population. The next step will be to conduct another data collection exercise with DAP (complemented, with interviews) involving more schools and teachers at the end of the first year of teaching programming in June 2019.

References

- Bandura, A. (1997). *Self-efficacy. The exercise of control* (13th ed.). New York: W. H. Freeman and Company.
- Bandura, A. (2000). Exercise of human agency through collective efficacy. *Current Directions in Psychological Science*, 9(3), 75–78.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101.
- Eells, R. J. (2011). Meta-Analysis of the Relationship Between Collective Teacher Efficacy and Student Achievement. Layola University.
- Fahrman, B., Norström, P., Gumaelius, L., & Skogh, I.-B. (2019). Experienced technology teachers' teaching practices. *International Journal of Technology and Design Education*. <https://doi.org/10.1007/s10798-019-09494-9>
- Hartell, E. (2013). Looking for a glimpse in the eye: A descriptive study of teachers' work with assessment in technology education. In *Technology Teachers as Researchers: Philosophical and Empirical Technology Education Studies in the Swedish TUFF Research School*. <https://doi.org/10.1007/978-94-6209-443-7>
- Hartell, E. (2018). Teachers' Self-Efficacy in Assessment in Technology Education. In M. J. de Vries (Ed.), *Springer International Handbook of Education: Handbook of Technology Education* (1st ed., pp. 785–800). Springer. http://doi.org/10.1007/978-3-319-38889-2_56-1
- Hattie, J. (2016). Shifting away from distractions to improve Australia's schools: Time for a Reboot Jack Keating Memorial Lecture (p. 24). Melbourne: University of Melbourne. Retrieved from http://education.unimelb.edu.au/_data/assets/pdf_file/0008/1993904/Deans-lecture-June-2016-Jack-Keating-lecture.pdf
- Nilsson, P. (2008). Learning to Teach and Teaching to Learn Primary science student teachers' complex journey from learners to teachers. Linköping university, Norrköping.
- Palmer, D., Dixon, J., & Archer, J. (2015). Changes in Science Teaching Self-efficacy among Primary Teacher Education Students. *Australian Journal of Teacher Education*, 40(12). <http://doi.org/10.14221/ajte.2015v40n12.3>
- Rohaan, E. J., Taconis, R., & Jochems, W. M. G. (2012). Analysing teacher knowledge for technology education in primary schools. *International Journal of Technology and Design Education*, 22(3), 271–280. <https://doi.org/10.1007/s10798-010-9147-z>
- SALAR (2018) Swedish Association of Local Authorities and Regions (Sveriges Kommuner och Landsting (SKL), LIKA tool <https://likalarare.skl.se>
- Statens Skolverk (2018). *Curriculum for the compulsory school, preschool class and school-age educare 2011 (rev 2018)* (2018th ed.). Stockholm, Sweden: Statens skolverk (The Swedish National Agency for Education).
- van Aalderen-Smeets, S. I., & Walma van der Molen, J. H. (2015). Improving primary teachers' attitudes toward science by attitude-focused professional development. *Journal of Research in Science Teaching*, 52(5), 710–734. <https://doi.org/10.1002/tea.21218>

- van Aalderen-Smeets, S. I., Walma van der Molen, J. H., & Asma, L. J. F. (2012). Primary teachers' attitudes toward science: A new theoretical framework. *Science Education*, 96(1), 158–182. <https://doi.org/10.1002/sce.20467>
- van Aalderen-Smeets, S., & Walma van der Molen, J. (2013). Measuring Primary Teachers' Attitudes Toward Teaching Science: Development of the Dimensions of Attitude Toward Science (DAS) Instrument. *International Journal of Science Education*, 35(4), 577–600. <https://doi.org/10.1080/09500693.2012.755576>

Fashion design education: effects of users as design core and inspirational source.

Neshane Harvey, Piet Ankiewicz, Francois Van as



Neshane Harvey
University of Johannesburg
South Africa
neshaneh@uj.ac.za



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



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

ABSTRACT

Simulating industry practice, pedagogical values and strategies in mainstream tertiary fashion design education (FDE) foreground that students typically research fashion trends that involve visual representations through collated secondary images to drive the design process ultimately evoking and representing inspiration, imagination, intuition and emotion. This manifests in personal self-expression whereby students learn to become lone-genius designers who primarily design for themselves or for fictional users, based on their own expert design knowledge. Human-centered design (HCD), which locates users, as well as their voice and needs as the nucleus of design and source of inspiration, is an emerging alternative strategy. However, in the under-developed research area of FDE, a HCD approach has not been explored within a higher education context. Thus, the effects of users as nucleus and inspirational foundation from which to drive design are unclear. Following research among first-year fashion design students, this paper aims to deliberate on the effects of positioning users as the design nucleus and inspiration for design practice. This aim is located in the following research question: what are the effects of positioning users as the design nucleus and inspirational driver for design practice in FDE? A HCD approach is a philosophy or mind-set that changes the way that design and development processes are seen and practiced (Norman, 2013; Sanders & Stappers, 2012). HCD is a unified process involving active collaboration and consultation with users throughout the design and development phases (Hanington, 2010). Hence, HCD places people (users) as well as their voices, needs, desires, experiences and behaviours as the nucleus of design and source of inspiration (IDEO, 2015; Keinonen, 2010; Norman, 2013; Sanders & Stappers, 2014; Steen, 2011). Empirical data were collected through participant observation, semi-structured questionnaires completed by students, and semi-structured interviews with educators. These data were analysed via a constant comparative method of analysis. The findings show that users as design nucleus and inspirational driver changed students' mind-set and foregrounded new design knowledge for alternative, externally-driven design processes and practice that foster design with empathy rather than for the self.

Key words: Fashion design education, human-centered design

INTRODUCTION AND CONTEXT OF THE STUDY

Professional fashion designers research fashion trends and draw on inspiration to generate design concepts in order to develop clothing products (Bye, 2010). Generally, fashion designers select visual inspirational imagery and from these borrow design elements to develop their own ideas (Lee & Jirousek, 2015). Such inspiration, in the form of the designer's emotions, vision, self-expression and authenticity, is a key driver of fashion design practice (Aspelund, 2010; Lee & Jirousek, 2015). However, user participation in design processes remains almost non-existent (Bye, 2010).

Simulating this industry practice, pedagogical strategies in mainstream tertiary fashion design education (FDE) foreground that students research, for example, socio-cultural, economic and lifestyle fashion trends, as well as fashion forecasting to categorise these into themes of colour, fabric and design style (Shin & Cassidy, 2015). As such, design project briefs include, for example, a theme or fashion trend, a season and a target market category such as ready-to-wear. These design projects necessitate that students engage with research that conventionally encompasses visual representation of secondary images collected in the form of mood boards, which are used to drive creativity in the design process (Aspelund, 2010; Cassidy, 2008). The mood board is a central part of the design process as it visually represents and communicates design concepts and thinking that relate to, for example, explicit fashion trends, colour palettes, fabrication and target market categories (Cassidy, 2008). These visual boards evoke and represent inspiration, imagination, meaning creation, the look and feel of designs, emotions and aesthetic preferences (Aspelund, 2010; De Wet, 2017). South African FDE imitates the same industry practice as well as mainstream pedagogical strategies in design practice. The implications of such pedagogical strategies are two-fold. Firstly, FDE demonstrates reliance on secondary visual research in order to drive fashion design process activities. Secondly, it fosters a culture of what Muratovski (2016, p. xxx) refers to as "inward-looking practice" manifesting in design knowledge from a personal lens and self-expression through which students learn to become lone-genius designers primarily designing for themselves. Hall and Logo (2015) confirm that fashion design students continue to design for themselves because of insufficient opportunity to design for or with real users. International trend forecaster, Edelkoort (2017), argues that FDE appears outdated, lacks transformation and continues to educate students to become 'star' designers. To counteract this situation, Muratovski (2016, p. xxx) calls for an "externally-driven process" which positions people and their needs as the design core.

Human-centered design (HCD), which locates users, and their voice and needs, as the core inspiration for design, is an emerging alternative strategy. Some scholars note that HCD is the same as user-centered design (Friess, 2010; Keinonen, 2010). However, Sanders and Stappers (2012) reject this, arguing that there is a difference between user-centered design and HCD because the former consider users as subjects of study while HCD position users as partners. It is evident that there are tensions between user-centered design and HCD.

However, in the under-developed research area of FDE, a HCD approach has not been explored within a higher education context. Thus, the effects of users as the nucleus and inspirational foundation from which to drive design are unclear. By examining alternative pedagogical strategies implemented with first-year fashion design students, this paper aims to deliberate on the effects of positioning users as the design nucleus and inspiration for design practice. The authors note that effects refer not to cause and effect relations, but to participant views and experiences. This aim situates itself in the research question: what are the effects of positioning users as the design nucleus and inspirational driver for design practice in FDE?

THEORETICAL FRAMEWORK

HCD is an approach, philosophy or mind-set that shifts the way that design and development processes are seen and practiced (Norman, 2013; Sanders & Stappers, 2012). As such, HCD is a unified process involving active collaboration and consultation with users throughout the design and development stages (Hanington, 2010).

HCD aims to develop products or services that harmonise with “users’ practices, needs and preferences” (Steen, 2011, p. 45). Likewise, understanding the context of the design in which the product is used, coupled with an understanding of users’ needs and preferences act as fundamental input into the design process (Endsley & Jones, 2012; Wilkinson & De Angeli, 2014). User participation in the early design process stage eliminates designers’ individual design knowledge, skills and philosophies (Wilkinson & De Angeli, 2014). Therefore, HCD places users as well as their voices, needs, desires, experiences and behaviours at the core of design and inspiration (IDEO, 2015; Keinonen, 2010; Norman, 2013; Sanders & Stappers, 2014; Steen, 2011). As a result, HCD challenges mainstream design practice, which places greater emphasis on designers and material products (Norman, 2013). The implication of this is that users are no longer viewed as passive subjects to be observed and studied through quantitative data collection methods and analysis.

Rather, for HCD, IDEO (2015) recommends qualitative data collection methods, such as semi-structured, individual and focus group interviews as well as narratives with actual users as participants in data collection. Similarly, designers generate, analyse and interpret user-generated data and design ideas (Hanington, 2010; Sanders & Stappers, 2014). The implications are that, HCD grounds itself in primary data collection methods, which aim to understand situations by gathering rich description, as opposed to secondary or statistical research. More prevalent is that designers assume the dual role of designer and researcher. Therefore, HCD is about designer and user collaboration throughout the design process stages and design development culminating in co-design, collective learning, co-creativity and active user participation (Hanington, 2010; Steen, 2011; Sanders & Stappers, 2012). In design development, users become prototype evaluators and critical feedback providers to support refinement before designers finalise design solutions and develop products (IDEO, 2015; International Organization of Standards 2010).

RESEARCH DESIGN AND METHODOLOGY

This inquiry forms part of a larger design-based research project with two teaching and learning iteration cycles in the form of design projects. To transform FDE through a HCD approach, the researcher (main author) developed design projects, which were structured around assessment briefs, for implementation with first-year fashion design students at an urban South African higher education institution. These design project briefs served as the assessment method using the following four assessment instruments: 1) a design journal to record, justify and make explicit all design and development activities, 2) a two-dimensional artistic fashion illustration with technical drawings of the final design solution, 3) three-dimensional prototypes, and 4) a final three-dimensional manufactured, wearable product. For the first teaching and learning iteration cycle, the design project duration extended over four weeks (three days per week) comprising of both contact sessions with educators and non-contact sessions for self-directed student learning. However, by the end of the second week, it became obvious that not enough time was allocated for the design project. Therefore, for the second teaching and learning iteration cycle, the design project timeframe was structured to include three days per week over seven weeks.

Both design projects aimed at installing users as the design core and primary inspirational source as the overarching approach to design, prototype and develop a wearable product. Students could not draw on secondary visual inspiration and manifestations of personal design knowledge as well as self-expression to drive their fashion design process activities. On the contrary, pedagogical strategies required students to: 1) engage in qualitative conversations to establish the context of design use, the design needs and preferences of users, and 2) in collaboration, co-design and develop a product with users. These pedagogical strategies differed from the manner in which students are traditionally educated to engage with research and design process activities as described earlier.

Although users are at the core of design activities in HCD, the pedagogical strategies deployed could not completely imitate professional practice. Hence, following the guidelines of studio-based pedagogy, these pedagogical strategies encompassed a simulated situation whereby students role-played in design teams encompassing two students, with one assuming the role of designer and the other that of user to generate design knowledge and engage with design process and product development activities. Due to uneven student numbers during the second iteration cycle, one design team comprised of one designer and two users. Regardless, all students had autonomy to select design team members and their respective roles.

With a qualitative approach embedded in design-based research, a purposive sampling method guided participant selection. Three participant sub-sets were involved, namely 24 (first iteration cycle) and 23 (second iteration cycle) first-year fashion design students as well as two educators who were responsible for teaching either design or product development activities to these first-year students and, finally, the researcher. The researcher assumed a dual role of observer and participant. As primary observer, the researcher assumed the role of data collection instrument during the teaching and learning iteration cycles. As secondary participant, the researcher assumed the role of designing the design project briefs in collaboration with both educators but also facilitated the teaching of theoretical aspects of HCD as required to support its implementation within the design projects.

With pre-drafted information disclosure and informed consent from participants, qualitative data collection methods entailed participant observation, semi-structured questionnaires completed by students and semi-structured interviews with the educators. With regard to participant observation, the researcher observed, explored and documented the design process activity tasks and prototype evaluations as executed by participating students and the manner in which these actions unfolded in a way that positioned the user as design core and source of inspiration. Participant observation raw data were captured via planned observational schedules.

In addition, at the end of each teaching and learning iteration cycle, self-administered, hard-copy questionnaires were collected from participating students. These aimed at ascertaining their views and experiences regarding users as design nucleus and inspirational source. Serving the same purpose as the questionnaires, individual, face-to-face, semi-structured interviews were conducted with the two educators. These interviews were digitally recorded and transcribed verbatim. Employing multiple methods of data collection from various participant sub-sets ensured research trustworthiness through triangulation. As such, multiple views relating to the same situation supported rich, thick description emerging from data analysis.

Following Merriam's (2009) recommendation, data from participant observation, student semi-structured questionnaires and educator semi-structured interviews were analysed via a constant comparative method with the application of Atlas.ti. Data analysis followed Saldaña's (2016, p. 14) "streamlined codes-to theory" model and unfolded in first and second coding cycles. The first coding cycle aimed at initial data coding via in vivo, open or simultaneous coding methods. The second coding cycle aimed at higher conceptual levels thus comparing fragments of raw data for emerging patterns, integrating, connecting, synthesising and considering categories for thematic interpretation. As such, data analysis of participant observations searched for emerging patterns regarding the design process and prototype evaluation activities executed by participating students. Similarly, data analysis of student questionnaires and educator interviews entailed searching for emerging patterns regarding the main effects of positioning users as design nucleus and inspiration for design practice.

FINDINGS

Emerging from the data analysis, the findings show that positioning users as the nucleus for and inspirational driver of design changed students' mind-sets and foregrounded new design knowledge for alternative, externally-driven design processes and practices that foster design with empathy rather than for the self. These findings are discussed with supporting participant raw data quotations under two categories. Participant raw data quotations are abbreviated as PO to reflect participant observation, SU to reflect raw data quotations from student questionnaires where the student adopted a user role, SD where the student adopted a designer role and E1 and E2 for the two educator interviews. Numbers accompany SU and SD abbreviations to differentiate individual student comments. Given that students role-played as designers and users, in the following discussion, they are referred to as designers and users.

Transforming from inward-looking to externally-driven practice

To frame the design problem and define user-specific design criteria and constraints, designers "placed the user at core and the source of inspiration" (PO). From data captured through participant observation, it became clear that designers assumed the role of primary instruments of data collection by engaging their respective users in qualitative conversations and probing strategies to elicit information about their needs, goals, preferences and contexts of design usage. The following comments from participant observation schedules support this interpretation: "designer was very engaging in conversation with user ... started to collect information from user" (PO) and "the designer probed the user to get clarification" (PO). As an audit trail, designers "documented what user said in a design journal" (PO). From this, designers and users collaboratively synthesised information by rationalising, selecting and deciding on a set of design criteria and constraints. Design teams jointly reflected on the data and collaboratively began to incubate design ideas through activities, such as sketching and experimental paper modelling. Some designers "made paper models as a means to show and visually communicate with user" (PO). Moreover, prototypes were made to bring the abstract design idea into reality. Users "evaluated the prototype providing detailed and clear feedback" (PO) to designers for the purpose of iteration before design solutions were finalised and products developed.

It is clear from participant observation findings that the embeddedness of users as design nucleus and inspiration for design practice, promoted by HCD, is different from mainstream pedagogical strategies in FDE that demonstrate reliance on secondary visual research as well as knowledge from a designer expert lens with which to drive design process activities. Likewise, the educators concurred that the designed pedagogical strategies counteracted traditional FDE in that it challenged participating students to think differently, acquire new design knowledge and compelled them to transform from a culture of inward-looking design

practice to an alternative, externally-driven process that positions people at its core. The following educator commentaries support this interpretation:

It really challenges the students because in the past what they usually do, when they have to design a garment, they literally open up a fashion magazine, pick a garment or go onto the internet and pick a design they like, adapt it and take it from there. But with the user-centered approach, they need to, they've got a set of constraints, what someone needs, and then they need to work within those constraints to develop a garment which is going to fit all those needs (E1).

In this case, the user becomes that inspiration and it also takes it one step further than that, they had to work with the user themselves. So, during every step of the process, the user had continuous input into the design decisions that were being made and all the information that goes to drive this project and to drive the design decisions, were (sic) actually drawn from the users' own preferences, their needs, their goals, that sort of thing (E2).

In so doing, an externally-driven practice transformed how fashion design students generally design, possibly due to its instrumentality in shaping a sense of design purpose, thinking about what to design and the design process actions required to achieve an intended outcome as opposed to merely abiding by fashion trends. As such, participating students, in their respective designer and user roles, thought about fashion design more deeply thus moving beyond self-expression and personal gratification. The following educator remark supports these findings:

So, I think that really made it a completely different type of project than what we are used to. It moved them away from that and had to make them really question why they are doing what they doing. Actually just forced them to really reflect on the purpose of design a little bit more and to start engaging with projects beyond just the level of trends (E2).

Corroborating these educator views, students, in their respective designer and user roles, remarked that they had better insight into how fashion design can be practiced by "putting the user as the core of inspiration" (SD3) and their needs at "the core of design" (SU1). As such, designers commented that it was "eye-opening" (SD6) and supported "out-of-the-box" (SD7) thinking as opposed to mainstream thinking about fashion design. Moreover, qualitative conversation about users' needs enhanced listening skills as remarked in one comment made by a user: "listening to what they say – their needs" (SU8). In doing so, the importance of users as design core and inspirational driver was considered as "one of the most important principles that runs through the entire process" (SU11). This made provision for active collaborative design between users and designers, which prompted users to be "more pro-active and ... want to do more to have the design come to life" (SU9). Similarly, one designer noted: "both I and the user benefited a lot from seeing each other's viewpoints and collaborating on the project. I also noticed, the user didn't feel like a subject but rather and active participant" (SD2). More prevalent is that designers felt that it enhanced and streamlined design process activities making it "less complicated" (SD4). This emerged from a sense of direction regarding the purpose of design solutions to align with user needs as indicated in a designer's comment: "it works because in the end after all the research, we are able to come up with a design, well-suited design, based on users' needs" (SD6).

Despite the benefits, a disadvantage of such an approach is that it eradicates designer autonomy as shown in the remark made by a student in a designer role: "not having much

freedom because - you have the needs of the user to think about” (SD5). Nonetheless, in general, consideration of user needs shifted students’ practices towards design with empathy.

Design with empathy

Users as design core and source of inspiration evoked an empathetic approach on the part of designers. The following comment from a designer supports this view: “empathise throughout the process making them [user] be part of the entire process” (SD8). Intrinsically, designers no longer considered themselves as the lone-genius but rather claimed to become “more considerate of the user needs” (SD9) and more responsive towards user opinions to drive design. Similarly, users believed that their respective designers empathised with them by positioning themselves in the reality of others by taking a “closer look at understanding another person” (SU4). Users felt that when a designer situates the user as design nucleus, then that designer shows empathy and consideration for people as articulated in a user comment: “she cares about my needs. As the user, it allowed me to be more open” (SU2). As such, students in their respective user and designer roles concurred that the opportunity afforded possibilities for user receptiveness and communication of design ideas, which users seemed to value. This finding is supported by a designer comment that, “users get to express their ideas across” (SD2). Similarly, a user expressed the view that they were “not the subject of study but rather the source of inspiration” (SU7). Then again, design with empathy foregrounded a new sense of mindfulness for users in that they too became “aware that the designer’s input counts as much as yours does” (SU3), which highlights the significance of the designer’s voice and involvement. Hence, a general sense of awareness that design is about inclusivity and people’s views as opposed to simply being about the materialisation of an abstract idea. One user mentioned: “it helped me to be aware that design is not just having ideas that are random in your head and implementing them but it’s using ideas and opinions from the person or the people you are designing with” (SU3). Supporting these student views, one educator remarked that such an approach to FDE “encourages a bit of empathy” (E2) as students, in their respective designer and user roles, placed themselves in the role of the other person.

CONCLUSION

The findings demonstrate a move away from conventional pedagogical values and strategies in FDE whereby students typically research fashion trends using secondary visual research to evoke lone-genius, inward-looking practices and processes whereby students, in general, design predominately for themselves based on their own expert design knowledge.

HCD, which locates users as design core and inspiration, generates new design knowledge about user needs, goals, preferences and contexts of design usage via qualitative research strategies. This design knowledge supports and enhances design process activities thus shifting students’ design beliefs from an inward-looking mind-set to an externally-driven process that values inclusivity, collaboration, belonging and autonomy for both designers and users to express their voices and design ideas. As such, HCD, in embedding users as design core and inspiration, was instrumental in transforming students’ practices and aiding them in learning to design with empathy. HCD offers the potential for a new pedagogy that shifts from what Crowther (2013, p. 20) calls the “hidden curriculum” where authoritarian, master educator values and attitudes are transmitted, to one in which students are afforded opportunities, in designer and user roles, to co-create design knowledge and manifest their values and beliefs in design and development processes. Although this inquiry focussed on FDE due to the context-specific nature of design-based research, this new pedagogy may well be applicable to, for example, school-context design and technology education, architecture or industrial design where the nature of designed products as the outcome of the design process are different to that of fashion.

REFERENCE LIST

- Aspelund, K. (2010). *The design process* (2nd ed.). New York, NY: Fairchild Books.
- Bye, E. (2010). *Fashion design*. Oxford, United Kingdom: Berg.
- Cassidy, T. D. (2008). Mood boards: Current practice in learning and teaching strategies and students' understanding of the process. *International Journal of Fashion Design, Technology and Education*, 1(1), 43-54.
- Crowther, P. (2013). Understanding the signature pedagogy of the design studio and the opportunities for its technological enhancement. *Journal of Learning Design*, 6(3), 18-28.
- De Wet, A. J. C. (2017). An educational tool to encourage higher level thinking skills in the selection of images for fashion design mood boards: An action research approach. *International Journal of Fashion Design, Technology and Education*, 10(1), 16-25.
- Edelkoort, L. (2017, February, 9). *Anti-fashion: A manifesto for the next decade* [Video file]. Retrieved from: <https://www.businessoffashion.com/articles/voices/video/video-li-edelkoort-reads-her-anti-fashion-manifesto>.
- Endsley, M. R., & Jones, D. G. (2012). *Designing for situation awareness: An approach to user-centered design* (2nd ed.). London, United Kingdom: CRC Press.
- Friess, E. (2010). The sword of data: Does human-centered design fulfill its rhetorical responsibility. *Design Issues*, 26(3), 40-50.
- Hall, M. L., & Logo, M. A. (2015). Functional design: Exploring design for disability in a childrenswear course. In International Textile and Apparel Association (ITAA). *Proceedings of the Conference on International Textile and Apparel Association* (pp. 1-2). Santa Fe, New Mexico. Retrieved from: https://lib.dr.iastate.edu/cqi/viewcontent.cqi?article=1290&context=itaa_proceedings
- Hanington, B. M. (2010). Relevant and rigorous: Human-centered research and design education. *Design issues*, 26(3), 18-26.
- IDEO. (2015). *The field guide to human-centered design*. Retrieved from: https://bestgraz.org/wp-content/uploads/2015/09/Field-Guide-to-Human-Centered-Design_IDEOorg.pdf
- International Organization of Standards (ISO) (2010). *ISO 9241-210. Ergonomics of human-system interaction. Part 210: Human-centred design for interactive systems* (1st ed.). Geneva, Switzerland: International Origination of Standards. Retrieved from: <https://www.sis.se/api/document/preview/912053/>
- Keinonen, T. (2010). Protect and appreciate - Notes on the justification of user-centered. *International Journal of Design*, 4(1), 17-27.
- Lee, J. S., & Jirousek, C. (2015). The development of design ideas in the early apparel design process: A pilot study. *International Journal of Fashion Design, Technology and Education*, 8(2), 151-161.
- Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco, CA: Jossey-Bass.

- Muratovski, G. (2016). *Research for designers: A guide to methods and practice*. Los Angeles, CA: SAGE.
- Norman, D. (2013). *The design of everyday things* (Revised and expanded ed.). New York, NY: Basic Books.
- Saldaña, J. (2016). *The coding manual for qualitative researchers* (3rd ed.). London, United Kingdom: SAGE.
- Sanders, E. B. N., & Stappers, P. J. (2012). *Convivial toolbox: Generative research for the front end of design*. Amsterdam, Netherlands: BIS Publishers.
- Sanders, L., & Stappers, P. J. (2014). From designing to co-designing to collective dreaming: Three slices in time. *Interactions*, November – December, 24-33.
- Shin, M. J., & Cassidy, T. D. (2015). Designing a fashion driving forces website as an educational resource. *International Journal of Fashion Design, Technology and Education*, 8(2), 173-183.
- Steen, M. (2011). Tensions in human-centred design. *CoDesign*, 7(1), 45-60.
- Wilkinson, C. R., & De Angeli, A. (2014). Applying user centred and participatory design approaches to commercial product development. *Design Studies*, 35(6), 614-631.

The predictive capacity of spatial ability for knowledge retention in third level technology and engineering education.

Tomás Hyland, Jeffrey Buckley, Niall Seery, Seamus Gordon



Tomás Hyland
*University of Limerick,
Ireland*
tomas.hyland@ul.ie



Jeffrey Buckley
*Athlone Institute of
Technology, Ireland*
*KTH Royal Institute of
Technology, Sweden*
jbuckley@ait.it



Niall Seery
*Athlone Institute of
Technology, Ireland*
nseery@ait.it



Seamus Gordon
*University of Limerick,
Ireland*
seamus.gordon@ul.ie

ABSTRACT

It is well established that spatial ability correlates with STEM performance. This has been shown through substantial longitudinal evidence e.g. (Wai, Lubinski, & Benbow, 2009). Specifically, it has been demonstrated as an important factor in engineering and technology education consistently for the last two decades (Buckley, 2018; Sorby, 1999, 2009b). However, a causal explanation does not yet exist (Ramey & Uttal, 2017). Working with the hypothesis that spatial ability affects cognitive load while learning, this paper specifically investigates the impact it has on retention, a component of the information processing theory of learning (Simon, 1978), within an authentic classroom environment. This paper describes a conceptual replication of Hyland et al. (2018), investigating the effect of spatial ability on the ability to retain information associated with novel engineering concepts.

A cohort of students from within a common engineering module in an Institute of Technology in Ireland voluntarily participated in this study. Initially, three validated psychometric tests of spatial ability were administered to the cohort. After three weeks this was followed by an experimentally designed lecture on novel foundational engineering/technology content after which an associated retention test was administered. Perceived task experience and interest were also measured through 9-point Likert-type items at this time.

The result from Hyland et al. (2018) that spatial ability predicts knowledge retention associated with fundamental engineering concepts over and above interest was replicated. This is significant in terms of informing both pedagogy in technology and engineering fields, and for research associated with the foundational development of spatial ability.

Key Words: Engineering education, Spatial ability, Learning, Retention.

Introduction

Spatial ability, defined as “the ability to generate, retain, and manipulate abstract visual images” (Lohman, 1996, p. 126) has been found to correlate significantly with performance in Science, Technology, Engineering and Mathematics (STEM) disciplines (Wai et al., 2009). In terms of technology education, it has been found to correlate with performance on geometric problem solving tasks (Buckley, Seery, & Canty, 2018) and with performance in design (Lin, 2016). Similar findings are more prevalent in engineering education (Alias, Black, & Gray, 2002; Carbonell Carrera, Saorín Pérez, de la Torre Cantero, & Marrero González, 2011; Sorby, 2009a) and the importance of this correlation in terms of education is apparent through the variety of attempts made to design targeted spatial training interventions (Onyancha, Derov, & Kinsey, 2009; Sorby, Casey, Veurink, & Dulaney, 2013; Stieff & Uttal, 2015). Critically, spatial ability has been found to be malleable and susceptible to change through such interventions (Stieff & Uttal, 2015; Uttal et al., 2013). However, despite the work highlighting that spatial ability is educationally important and malleable, there is uncertainty as to why this cognitive ability has such profound implications (Ramey & Uttal, 2017).

It is posited that because spatial ability has been found to consistently correlate with STEM educational performance, that at some level it is having an impact on learning. Mayer (2002) describes learning as involving the acquisition of knowledge and subsequently Kirschner, Sweller and Clark (2006, p. 75) defined learning as “a change in long-term memory”. These definitions are associated with the information processing theory of learning which defines learning as “an active mental process involving the storage and retrieval of knowledge stored in memory” (Terrell, 2006, p. 254) and is based on the human cognitive architecture. In brief, the process of learning or acquiring knowledge involves a sensory input which is perceived in the sensory memory, assuming attention is given to this information it is then processed in the working memory and then encoded into the long-term memory. Once encoded, it can be retrieved from the long-term memory into the working memory again and is then visible through outputs such as educational test answers, behaviours etc. Sweller, Ayres and Kalyuga (2011) and Terrell (2006) provide a more accurate and complete description of this process. Assuming spatial ability has an effect on learning, based on this theory that suggests it has an effect on at least one of the cognitive processes associated with processing information. Therefore, it could affect how information is perceived, stored in short-term memory, processed in the working memory to be encoded into the long-term memory, and/or retrieved from the long-term memory. This study aims to investigate the potential impact that spatial ability has on the retention of information in the short-term memory, and is a conceptual replication of Hyland, Buckley, Seery, Power and Gordon (2018)

Results of Hyland et al. (2018)

Hyland et al. (2018), based on the work of Ruiter, Loyens and Paas (2017), investigated the relationships between spatial ability, interest in presented information, and task experience on the retention of novel information associated with fundamental engineering concepts. The methodology involved administering three validated psychometric tests of spatial ability to a cohort of university students, and analysing the results of these relative to Likert-type items concerning interest in pertinent content, perceived task experience, and performance in an immediate retention test of information presented in an authentic lecture. A number of statistically significant correlations were found including between spatial ability and performance on the retention test ($r = .317, p = .004$). The full correlation matrix is presented below (Table 1) in terms of the Spearman’s rho coefficient as the majority of the data is ordinal.

Table 5. Correlation matrix from Hyland et al. (2018).

		1	2	3	4	5	6	7	8
1. Spatial ability	ρ	–							
	p								
2. Retention	ρ	.206	–						
	p	.062							
3. Interest	ρ	.103	.368**	–					
	p	.356	.001						
4. Attention	ρ	-.106	.120	.467**	–				
	p	.341	.280	.000					
5. Effort focus	ρ	-.028	.051	.069	.028	–			
	p	.803	.647	.533	.801				
6. Effort understand	ρ	-.056	-.051	.178	.130	.650**	–		
	p	.613	.650	.107	.243	.000			
7. Lecture difficulty	ρ	-.187	-.216*	-.152	-.100	.058	.200	–	
	p	.091	.049	.169	.367	.600	.069		
8. Enjoyment	ρ	.135	.200	.505**	.315**	.136	.237*	-.040	–
	p	.225	.070	.000	.004	.220	.031	.719	
9. Question difficulty	ρ	.124	-.237*	-.130	.031	.017	.086	.406**	.040
	p	.266	.031	.242	.783	.879	.442	.000	.723

Note. **. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Additionally, Hyland et al. (2018) conducted a stepwise multiple regression considering performance on the retention test as the dependant variable all of the other variables from the correlation matrix as independent variables. The final model was statistically significant, ($F(3,79) = 8.916, p < .000$) and accounted for 25.3% of the variance in knowledge retention. The results are shown in Table 2 below.

Table 6. Stepwise multiple regression from Hyland et al. (2018).

IV	Model 1			Model 2			Model 3		
	B	SE B	β	B	SE B	β	B	SE B	β
1	1.220	.340	.371**	1.101	.330	.335**	.1.013	.325	.308**
2				2.532	.932	.272**	2.702	.916	.291**
3							-.696	.328	-.209**
R ²	.138			.210			.253		
ΔF	12.915**			7.372**			4.510**		

Note: ** $p < 0.1$. Independent variables (IV): 1 = interest, 2 = spatial ability, 3 = question difficulty. Dependant variable = retention.

The results of this work were interesting in that spatial ability was found to account for an additional 7.2% of the variance in knowledge retention above and beyond participants' interest in the content. To investigate the generalisability of this result, this study employed a conceptual replication of Hyland et al. (2018). The differences in method include:

- The study cohort from Hyland et al. (2018) consisted of 83 students (69 males and 14 females, $M_{age} = 18.19, SD_{age} = 1.18$) studying on an engineering programme in an Irish

University whereas the cohort from this study consisted of between 43 and 56 students (some participants missed testing sessions) studying on an engineering programme in an Irish Institute of Technology.

- The engineering content from Hyland et al. (2018) was associated with permanent and non-permanent methods of mechanical joining, whereas in this study the content was associated with gears.
- There were different lecturers delivering the content in both studies, however in both cases it was the students regular lecturer.

Aside from these variances the methods were identical. Full details of the method used in this study are presented below.

Method

Participants

The study was conducted with a 1st year cohort of engineering education students. A total of 76 students were invited to voluntarily engage with this study as part of their common engagement with an introductory module focussing on engineering mechanics. Participation required attending two testing sessions, each lasting one hour. A total of 56 students participated in the first session where they completed a battery of spatial tests. A total of 45 students participated in the second session where they engaged with a short declarative lecture, responded to Likert-type items associated with their experience of the lecture, and completed a retention test. In total, 43 students attended both sessions ($M_{age} = 20.91$, $SD_{age} = 5.95$) and of these 41 were male and 2 were female.

Instruments

Three psychometric tests of spatial ability were administered to participants. From the Kit of Factor-Referenced Cognitive Tests (Ekstrom, French, Harman, & Derman, 1976) the Paper Folding Test (PFT) and the Surface Development Test (SDT) were used. Additionally, the Purdue Spatial Visualization Test: Visualization of Rotations (PSVT:R) (Bodner & Guay, 1997; Guay, 1977) was used as it has been shown to be psychometrically sound specifically with engineering students (Maeda, Yoon, Kim-Kang, & Imbrie, 2013). These three tests were used as they each require a different cognitive action (i.e. mental folding, surface development, and mental rotations) and therefore through their combination, task related bias is reduced.

Participants also engaged with an experimental lecture. This was delivered for a period of 30 minutes by their regular lecturer. The content was new for all participants when considered as part of their formal undergraduate education. The lecture focused on mechanics, specifically gear trains, gear ratios and types of gears. A PowerPoint slideshow guided the delivery of the lecture. Prior to the beginning of the lecture, participants were informed that there would be a retention test directly after it.

The retention test contained 13 multiple part recall questions with a total of 24 declarative answers required. Questions specifically related to the content of the lecture. The answers for each question were presented visually on the slideshow and aurally by the lecturer. An example of a question with multiple answers required is; "What two things can gears change in a gear train". All answers were scored as either correct if entirely accurate (1 point) or incorrect (0 points). Students were given 20 minutes to complete the test.

In this study, task experience was explored based on the variables examined by Ruitter et al. (2017) which included self-reported interest in the lecture content, attention, investment to stay focused, effort required to understand the lecture content, lecture difficulty, enjoyment and post-lecture question of difficulty. A 9-point Likert-type question based on the Paas (1992) Cognitive Load Rating Scale was used to represent the above variables. For example, for self-

reported attention participants were asked to “Rate the level of interest you have in the lecture content” on a 9-point Likert-type scale from “very, very low interest” to “very, very high interest”.

Implementation

The first phase of the study involved participants attending a testing session where the three psychometric tests of spatial ability were administered. This was implemented within the participants’ regular lecture theatre. The session lasted for one hour, with six minutes allocated for the PFT, twelve minutes for the SDT and finally twenty minutes for the PSVT:R in line with their standard administration guidelines.

In the second phase of the study, participants engaged in the experimental lecture and knowledge retention test. This was administrated three weeks after the psychometric tests by the students’ regular lecturer. Directly after the lecture two researchers distributed the knowledge retention test. The participants engaged in the Likert-type questions related to the variables of interest, attention, effort required to focus, effort required to understand the lecture content, lecture difficulty, and enjoyment first, which was immediately followed by the knowledge retention questions and the final Likert-type item concerning post-lecture question difficulty.

Results

Descriptive statistics for each of the variables examined in this study are presented in Table 3. Skewness and kurtosis values for all tests were within acceptable limits of between ± 2 (Gravetter & Wallnau, 2014; Trochim & Donnelly, 2006).

The three psychometric tests of spatial ability all correlated positively with each other (average $r = .527$, $p < .01$). A factor analysis was conducted with the three psychometric tests as variables and the first factor accounted for a large proportion of the variance (68.63%) with factor loading ranging from .595 to .871. Therefore, following the approach used by Hambrick et al. (2012), a composite measure of spatial ability was created by averaging z-scores for each of the psychometric tests.

A correlation matrix is presented in Table 4. The Spearman’s Rho statistic was used to account for the ordinal data collected through the Likert-type items. As the spatial ability variable and retention test represent scaled data, a Pearson’s correlation was computed between these variables and a statistically significant correlation ($r = .379$, $p = .012$, $n = 43$) was observed.

Table 7. Descriptive statistics.

	N	Min	Max	M	SD	Skewness	Kurtosis
PFT	56	4	19	11.429	3.607	.274	-.672
SDT	56	5	60	37.143	15.182	-.480	-.805
PSVT:R	56	6	30	20.554	5.556	-.631	.345
Retention	45	7	23	15.556	4.132	-.402	-.507
Interest	43	1	9	6.628	1.398	-1.483	.709
Attention	43	3	9	6.093	1.231	-.265	.316
Effort focus	43	2	9	5.651	1.494	.097	.344
Effort understand	43	2	9	5.860	1.407	.205	1.335
Lecture difficulty	43	3	9	5.093	1.461	.264	-.253
Enjoyment	43	3	8	6.000	1.175	-.554	-.317
Question difficulty	42	2	7	4.881	1.383	-.416	-.701

Table 8. Spearman's Rho correlation matrix (n = 40-56).

		1	2	3	4	5	6	7	8
1. Spatial ability	ρ	–							
	p								
2. Retention	ρ	.372*	–						
	p	.014							
3. Interest	ρ	.317*	.400**	–					
	p	.044	.008						
4. Attention	ρ	.106	.288	.618**	–				
	p	.509	.061	.000					
5. Effort focus	ρ	-.210	-.201	.218	.286	–			
	p	.187	.196	.161	.063				
6. Effort understand	ρ	-.190	-.094	.265	.426**	.577**	–		
	p	.235	.550	.086	.004	.000			
7. Lecture difficulty	ρ	-.279	-.095	-.142	.065	.278	.387*	–	
	p	.078	.543	.363	.681	.072	.010		
8. Enjoyment	ρ	.094	.180	.451**	.374*	.174	.429**	.069	–
	p	.560	.247	.002	.013	.263	.004	.659	
9. Question difficulty	ρ	.230	-.307*	-.057	-.056	.162	.134	.226	.053
	p	.153	.048	.722	.728	.312	.404	.155	.742

Note. **. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

A total of 11 statistically significant correlations were observed in the data, 8 of which replicated the findings of Hyland et al. (2018). These include the correlations between spatial ability and retention ($r = .379$, $p = .012$) which is of particular interest as the purpose of this study was to collect data to confirm the relationship between these variables. Additionally, the correlations between retention and interest in the lecture content ($\rho = .400$, $p = .008$), the perceived amount of attention paid and interest ($\rho = .618$, $p < .000$), retention and perceived question difficulty ($\rho = -.307$, $p = .088$), enjoyment and interest ($\rho = .451$, $p = .002$), enjoyment and attention paid ($\rho = .374$, $p = .013$), effort required to stay focused and to understand the content ($\rho = .577$, $p < .000$), and enjoyment and the amount of effort perceived to be required to understand the content ($\rho = .429$, $p = .004$) were also found to replicate.

Finally, a multiple linear regression analysis was conducted with the performance in the retention test considered as the dependant variable, and interest in the lecture content, spatial ability, and perceived question difficulty entered as independent variables. The model was statistically significant ($F(3,35) = 5.856$, $p = .002$) with the independent variables collectively accounting for 33.4% of the variance in knowledge retention. Both interest in the content and spatial ability were significant predictors in the model ($p < .05$), and spatial ability accounted for 4.8% of the variance in knowledge retention, however this was not a significant change ($\rho = .134$)

Conclusion

The study aspired to gain further insight into the role of spatial ability in learning in engineering education. Specifically, the study explored whether spatial ability had an effect on knowledge acquisition through having a relationship with students' capacity to retain recently presented information. The results of this study replicated those of Hyland et al. (2018) in this regard, and add further credibility to the evidence suggesting that spatial ability does relate to knowledge retention. Considering that this result replicated, this suggests that one element of the causal relationship between spatial ability and performance in STEM education in that

spatial ability has a positive impact on learning, over and above student interest, due to its predictive capacity for knowledge retention.

To conclude, the results of this study infer two primary recommendations for practice. First, student interest is a key factor in their retention of knowledge in the short term. The results do not permit the recommendation of any particular pedagogical approaches, but they do allow for the recommendation that educators clearly convey the importance and relevance of knowledge learning outcomes to students in an attempt to foster internal interest among them. Second, the understanding that spatial ability has an impact on knowledge retention provides evidence which can be used to inform spatial training interventions and future research. Critically, this result suggests a foundational association at a cognitive level adding validity to the effects seen through interventions. It also means that effort should continue to be focussed on developing such interventions from a foundational perspective to train spatial ability, and that activities associated with knowledge retention, such as n-back training, may provide additional effects if integrated into currently validated interventions.

References

- Alias, M., Black, T., & Gray, D. (2002). Effect of instructions on spatial visualisation ability in civil engineering students. *International Education Journal*, 3(1), 1–12.
- Bodner, G., & Guay, R. (1997). The purdue visualization of rotations test. *The Chemical Educator*, 2(4), 1–17.
- Buckley, J. (2018). *Investigating the role of spatial ability as a factor of human intelligence in technology education: Towards a causal theory of the relationship between spa*. KTH Royal Institute of Technology.
- Buckley, J., Seery, N., & Canty, D. (2018). Investigating the use of spatial reasoning strategies in geometric problem solving. *International Journal of Technology and Design Education*. <https://doi.org/10.1007/s10798-018-9446-3>
- Carbonell Carrera, C., Saorín Pérez, J. L., de la Torre Cantero, J., & Marrero González, A. M. (2011). Engineers' spatial orientation ability development at the european space for higher education. *European Journal of Engineering Education*, 36(5), 505–512.
- Ekstrom, R., French, J., Harman, H., & Derman, D. (1976). *Kit of factor-referenced cognitive tests*. Princeton, New Jersey: Educational Testing Service.
- Gravetter, F., & Wallnau, L. (2014). *Essentials of statistics for the behavioural sciences*. California: Wadsworth.
- Guay, R. (1977). *Purdue spatial visualization test: Rotations*. West Lafayette, Indiana: Purdue Research Foundation.
- Hambrick, D., Libarkin, J., Petcovic, H., Baker, K., Elkins, J., Callahan, C., ... LaDue, N. (2012). A test of the circumvention-of-limits hypothesis in scientific problem solving: The case of geological bedrock mapping. *Journal of Experimental Psychology: General*, 141(3), 397–403.
- Hyland, T., Buckley, J., Seery, N., Power, J., & Gordon, S. (2018). Investigating the Relationships between Spatial Ability, Interest, and Task Experience on Knowledge Retention in Engineering Education. In N. Seery, J. Buckley, D. Canty, & J. Phelan (Eds.), *PATT2018: Research and Practice in Technology Education: Perspectives on Human Capacity and Development*. Westmeath, Ireland: Athlone Institute of Technology (pp. 263–269).
- Kirschner, P., Sweller, J., & Clark, R. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, 41(2), 75–86.
- Lin, H. (2016). Influence of design training and spatial solution strategies on spatial ability performance. *International Journal of Technology and Design Education*, 2016(1), 123–131.

- Lohman, D. (1996). Spatial ability and g. In I. Dennin & P. Tapsfield (Eds.), *Human Abilities: Their Nature and Measurement* (pp. 97–116). New Jersey: Lawrence Erlbaum Associates.
- 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.
- Mayer, R. (2002). Rote versus meaningful learning. *Theory into Practice*, 41(4), 226–232.
- Onyancha, R., Deroy, M., & Kinsey, B. (2009). Improvements in Spatial Ability as a Result of Targeted Training and Computer-Aided Design Software Use: Analyses of Object Geometric and Rotation Types. *Journal of Engineering Education*, 98(2), 157–167.
- Paas, F. (1992). Training strategies for attaining transfer of problem-solving Skill in statistics: A cognitive-load approach. *Journal of Educational Psychology*, 84(4), 429–434.
- Ramey, K., & Uttal, D. (2017). Making sense of space: Distributed spatial sensemaking in a middle school summer engineering camp. *Journal of the Learning Sciences*, 26(2), 277–319.
- Ruiter, M., Loyens, S., & Paas, F. (2017). The effects of cycling on a desk bike on attention, retention and mood during a video lecture. *Applied Cognitive Psychology*, 31(6), 593–603.
- Simon, H. A. (1978). Information-processing theory of human problem solving. *Handbook of Learning and Cognitive Processes*, 5, 271–295. <https://doi.org/10.4324/9781315770314>
- Sorby, S. (1999). Developing 3-D spatial visualization skills. *Engineering Design Graphics Journal*, 63(2), 21–32.
- Sorby, S. (2009a). Educational research in developing 3-D spatial skills for engineering students. *International Journal of Science Education*, 31(3), 459–480.
- Sorby, S. (2009b). Educational Research in Developing 3 - D Spatial Skills for Engineering Students Educational Research in Developing 3-D Spatial Skills for Engineering. (September 2014), 37–41. <https://doi.org/10.1080/09500690802595839>
- Sorby, S., Casey, B., Veurink, N., & Dulaney, A. (2013). The role of spatial training in improving spatial and calculus performance in engineering students. *Learning and Individual Differences*, 26(1), 20–29.
- Stieff, M., & Uttal, D. (2015). How much can spatial training improve STEM achievement? *Educational Psychology Review*, 27(4), 607–615.
- Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. New York: Springer.
- Terrell, M. (2006). Anatomy of learning: Instructional design principles for the anatomical sciences. *The Anatomical Record (Part B: The New Anatomist)*, 289(B), 252–260.
- Trochim, W., & Donnelly, J. (2006). *The research methods knowledge base*. Ohio: Atomic Dog Publishing.
- Uttal, D., Meadow, N., Tipton, E., Hand, L., Alden, A., Warren, C., & Newcombe, N. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin*, 139(2), 352–402.
- Wai, J., Lubinski, D., & Benbow, C. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, 101(4), 817–835.

Pre-Service Teachers' Perceptions of Pedagogical Approaches to STEM Education; Design and Technology.

Dawne Irving Bell



Dawne Irving Bell
Edge Hill University
England, UK
BellD@edgehill.ac.uk

ABSTRACT

The purpose of this research is to gain an understanding of the impact personal narratives have in influencing the construction of pre-service design and technology teachers' professional identity. Work presented explores how personal experiences impact on the personal development and pedagogical practices in relation to the subject they are training to teach. Drawing on their experience of learning Science, Technology, Engineering and Math (STEM) subjects as pupils, this work explores the impact this has had upon the formation of their own self-identity as they train to become teachers of a STEM related subject discipline within secondary education in England.

To help ensure congruence between the ontological and epistemological position of the researcher, drawing upon the philosophical field of symbolic interactionism, the adopted research method is one that is informed by constructivist grounded theory (Charmaz, 2006, 2014).

Embracing an abductive methodology, which encourages the consideration of all possible theoretical outcomes, reasoning begins after scrutiny of the data, rather than forcing one to emerge through the process of data analysis. The approach also encompassed the notion of reflexivity, which helps to sensitize the researcher to issues within the data set and helps to support the construction of theory.

Following analysis, findings suggest that pre-service teachers' personal narratives play a key role in the formation of their identity as teachers of design and technology. Emergent themes under discussion include participants' emotion and personal disposition, their attitudes and approaches towards learning, and the role perceived deficiency in subject knowledge plays in limiting personal growth and the development of identity.

Keywords: STEM, design and technology, teacher identity, subject knowledge gap, pedagogical approaches

Introduction / Rationale

Set within the context of Science, Technology, Engineering and Math (STEM) education within secondary education in England, the purpose of this research study is to gain a better understanding of the impact that personal narratives have in influencing the construction of pre-service design and technology teachers' professional identities.

Work presented explores how the meaning assigned to one's own sociocultural background, childhood memories, life and learning experiences, and one's experience of learning as a pupil shapes pre-service teacher approaches to learning, and how in turn this influences their pedagogical practice (approaches to teaching). As such the rationale behind this study is to explore for illumination and analysis how these experience related beliefs influence the formation of emergent teacher identities and subsequently to identify potential implications for pre-service design and technology teacher education.

Background

Prior to outlining the research that has been undertaken, it is necessary first to lay out the context within which design and technology teacher training within England currently occurs. This is to make clear my ontological position and to draw to your attention to the meaning assigned to my understanding and interpretation of design and technology curriculum related documentation and current United Kingdom (UK) educational policy.

Hence this paper begins from the stance that within the curriculum some subjects are perceived to be of more value than others (Robinson, 2011; Bleazby, 2015; Breslin, 2016). This is particularly prevalent within the STEM disciplines, where compared to science and mathematics, design and technology is very much the poor relation, marginalised and constantly struggling to retain a foothold within the national curriculum (Bell *et al.* 2016). It is well documented that within England, arguably the country where design and technology originated, the subject faces significant challenges. As a discipline, design and technology was created as a vehicle for the practical application of Mathematics and Science (DES, 1988), however, whilst the subject has much to offer in supporting the effectual development of STEM literacy, this potential has not been fulfilled (Bell, 2016).

The reasons for this are complex and drawn from the research explanations include the subject's vocational nature and origins in manual labour (Paechter, 1993, 1995), and its constantly changing body of knowledge (Bell *et al.* 2016). However, irrespective of the reason(s) as to why design and technology is not perceived as being of equal status with its curriculum counterparts, the evidence of its relegation is clear. Examples including the subject's exclusion from the English Baccalaureate (DfE, 2016), which has resulted in restricted access to funding, less curriculum time, and limited teacher training bursary payments available to those studying design and technology (DfE, 2019).

According to Lortie (1975) our values and beliefs about teaching, how a teacher should act and be, form at an early age (Hargreaves, 2010). Within the literature while previous studies have explored the influence experiences have on identity construction (Bukor, 2015), and teacher commitment (Day *et al.* 2006), the development of learning and teaching (Prosser & Trigwell, 1999; Trigwell *et al.* 1999; Lindblom-Ylänne *et al.* 2006; Van Driel & Berry, 2012), the impact of educational reform (Van Veen *et al.* 2005; Lee & Yin, 2011; Lee *et al.* 2013), cognitive, social, and emotional processes (Beauchamp & Thomas 2009; Yuan & Lee, 2015), stress (Zembylas, 2003a, b; Van Veen & Sleegers 2006; Timoštšuk & Ugaste 2012) and efficacy (Bandura, 1994; Tschannen-Moran *et al.* 1998), and in their work Yuan and Lee (2016) suggest that how pre-service teachers construct their identity is still a topic largely unexplored.

A review of the literature revealed few studies that explore the relationship between beliefs and teaching behaviours. Hence, amid my concerns for the subject, and within the context of the challenges faced, stemming from my personal curiosity in wanting to understand what it is that, despite these difficulties, drives those who seek to become teachers of Design and Technology. With the purpose of being better able to understand how perceptions and experience-related beliefs influence the formation of pre-service identities of STEM teachers, my research question is:

What influence do the meanings assigned to previous learning experiences, including personal perceptions of subject knowledge, have on the formation of design and technology pre-service teacher professional identity?

A Review of the Literature

This study adopts an approach that is informed by grounded theory, where traditionally a review of the literature is not undertaken prior to collection and analysis of the data. This is in order to avoid stifling, forcing or contaminating the data (Glaser & Strauss, 1967:37), however, it was not Glaser and Strauss's (1967:3) intention that researchers approach their work as '*tabula rasa*' (blank slates), but that research undertaken should be approached with an "*open mind, not an empty head*" (Dey, 1993:63).

Within this study the literature provides an opportunity to look at the field under investigation from different perspectives. Positing identity as a central theme, other areas under exploration include learning and teaching, and subject knowledge. However mindful of the large amounts of literature, because the focus of my research is specific to the socially constructed development of teacher identity, papers falling outside of this field have not been subject to detailed review.

According to Beauchamp and Thomas "*A major hurdle in gaining an understanding of identity is resolving a definition of it*" (2009:176) therefore within the context and challenges outlined, which frame the rationale for undertaking this study, before presenting a brief review of the relevant literature, it may be helpful, for clarify, to define within the context of this work the term identity. Identity is a term that may be used to define how people perceive themselves, or how society perceives them (Gross & Hochberg, 2014). It can refer to a form of self-understanding (Kelchtermans, 2005) or be 'a shifting dynamic informed through interactions' (Rodgers & Scott, 2008:736).

According to Beijaard *et al.* (2004) identity is multi-faceted and emerges from an ongoing process of interpretation and re-interpretation, of who one considers oneself to be, and who one would like to become. This aligns with insights offered by Beauchamp and Thomas (2009) who explore the link between identity and agency, the role emotion has in shaping identity, and the power of stories and discourse in supporting our understanding of identity.

From this perspective identity may be defined as being dynamic, rather than stable, and of relevance within the context of this study may be "*shaped and reshaped in interaction with others in a professional context*" (Beauchamp & Thomas, 2009:177, 178).

Linking identity to teacher education and self-efficacy, identity has been likened to self-confidence, consisting of a teacher's belief in their own capacity to organise and execute required courses of action (Bandura 1997:3) and associated with autonomy, self-motivation (Midgley *et al.* 1989) and an increased use of '*hands on*' teaching methods (Enochs & Riggs, 1990). Guskey (1998) explored efficacy alongside receptivity to change and found that those with efficacy were more likely to be more open to the implementation of new practices.

Conversely, where teachers exhibited low self-efficacy, pedagogy tended to reflect the adoption of strict, traditional styles of teaching (Tschannen-Moran *et al.* 2007). While Baleghizadeh and Shakouri (2017:401) found that typically those teachers with stronger self-efficacy sought to enhance the learning process and thus increased satisfaction for both the teacher and student. Furthermore, they found that those with low efficacy, who considered lectures to be the most important part of their teaching, were less inclined to enhance learner autonomy and less likely to implement innovative teaching styles.

Methods and methodology

To help ensure congruence between my ontological and epistemological position, I have drawn upon the philosophical field of symbolic interactionism. Within this context symbolic interactionism explains how an individual's identity forms following reflection on their interactions with others, especially those who have had a significant influence on their lives (Mead, 1934). This is particularly important because from the perspective of pre-service teachers, whose identities are "*deeply embedded in their personal biography*" (Bukor, 2012:305), "*newcomers learning to teach enter teacher education looking backward on their years of school experience and project it into the present*" (Britzman, 2007:2).

As such, underpinned by an interpretivist ontology, the research method I have chosen is one that has been informed by constructivist grounded theory (Charmaz, 2006, 2014), which in adopting an abductive methodology, combines both inductive and deductive theory generating procedures. The result being that theoretical concepts are constructed, rather than being 'discovered', and with reasoning being undertaken after analysis of the data. This approach was adopted because it encouraged the consideration of all possible theoretical outcomes, rather than forcing one to emerge. Throughout work also encompassed the notion of reflexivity, which helped to sensitize me to emergent issues within the data set, an approach which helped to support the construction and generation of research findings.

Within this particular phase of the study work engaged nine participants, who at the time of their engagement were all following Post Graduate training routes, including Schools Direct, to become secondary age phase (children aged between 11-18 years old) design and technology teachers. For clarity Post Graduate refers to a training route roughly 9-11 months in duration for those already in possession of a subject related undergraduate level degree. School Direct is a Post Graduate route but in this iteration operates directly within a school (or hub of schools), rather than using a University as the training base. The cohort was roughly even with respect to the mix of gender (four female and 5 male participants) and comprised of participants training to teach the full range of design and technology subject disciplines.

Prior to participation the aims and purpose of the study were explained to participants and informed consent obtained. Data collection took the form of semi-structured interview with follow up email discourse. Interviews were undertaken in accordance with procedures advocated by Bowden and Green (2005), recorded and transcribed verbatim, with care taken to accurately record responses in order to avoid misrepresentation. Interviews took place in a neutral setting, at a time convenient to the participants, and always adhering to ethical guidance outlined by the British Educational Research Association (BERA, 2018).

In line with the chosen methods and methodological approach, concurrent data collection, generation and analysis occurred, with emergent outcomes from preceding research phases informing the next. Using methods advocated by Bryant and Charmaz (2007) and Charmaz (2014) while gathering data care was taken to ask exploratory, rather than interrogative questions, and during analysis coding procedures advocated by Glaser (1992) and Charmaz (2014) were employed.

Findings

The first questions posed asked participants about their recollections of being taught as a pupil and how they learned best. During later phases questioning sought to establish how participants thought the meaning assigned to their experiences would influence their approaches to teaching.

Irrespective of their age, gender, or subject discipline in recalling memories (pleasant or unpleasant) analysis showed subject knowledge to be constantly integral to participant responses.

Pleasant memories were of good teachers, and good teaching. Good teacher attributes included patience, tolerance, approachability, and enthusiasm. Good teaching was demonstrated by strong subject knowledge and an ability to explain things easily. Pleasant experiences related to practical activities, undertaken by confident teachers, who were unafraid to take a risk, and who explored a range of teaching strategies. When recalling pleasant memories (positive recollections) participants described wanting to emulate their favourite teachers, both in attitude and pedagogical approach. In these instances, the impact on the learner (their recollection of learning as experienced as a pupil) and learning was overwhelmingly positive, with participants talking about enjoyment, taking ownership of the work, developing a passion for the subject, personal development, and growth in confidence.

Conversely, unpleasant (negatively recalled experiences) recollections included accounts of poor teachers and bad teaching. Associated with these recollections were countless examples of the impact of poor teaching on their motivation and confidence as learners. Following initial analysis, moving from open to selective coding, participants were asked to articulate their experiences in relation to their own perceptions of the impact subject knowledge has on both teaching and learning. The iterative process undertaken during this phase was captured through the use of diagramming and is illustrated visually within Figure 1.0.

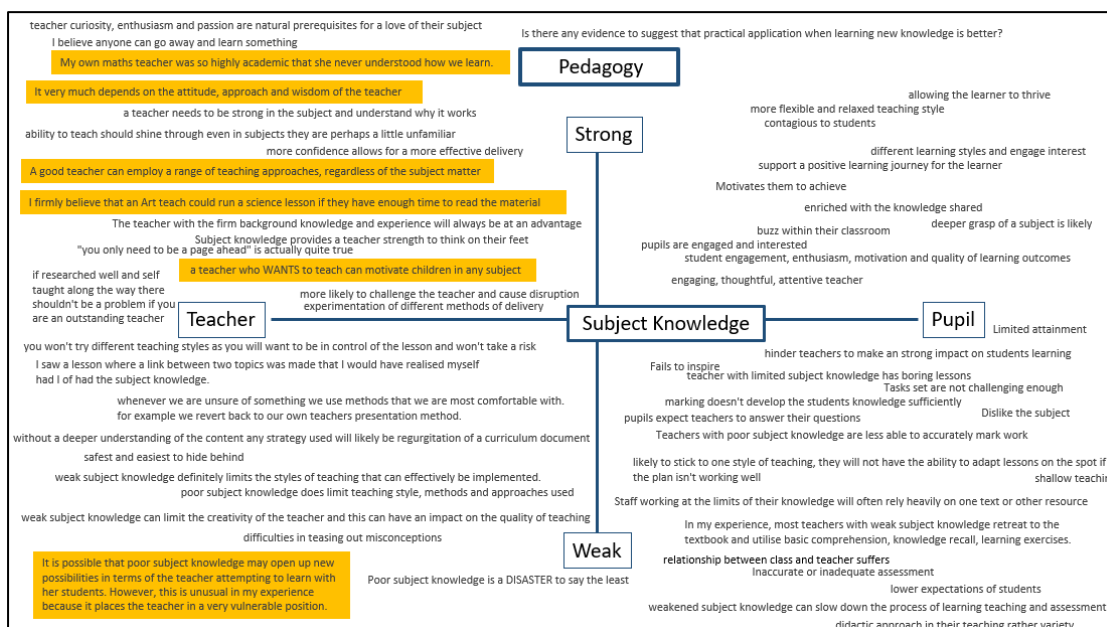


Figure 1.0

Visual analysis of data iteration around the central axis of subject knowledge:
The cross-correlation of pre-service teacher's perceptions.

As illustrated by this interview extract:

“the worst lesson definitely is where the teacher’s just standing there, and it’s almost like an assault of knowledge and then you have to sort of take it away and work out what it is that’s just happened to you”

The impact of poor pedagogical adaptation, where subject knowledge is delivered unrefined, with little or no consideration of how knowledge is received by the learner, can be significant. The sentiment expressed within this quotation is typical of feelings cited by participants. Perceptions of poor teaching were associated with weak subject knowledge:

“weak subject knowledge limits the range of teaching styles, if a teacher lacks knowledge, they are going to spend their time filling those gaps rather than looking at new and innovative ways of delivering knowledge.”

“Teachers with weaker subject knowledge are more inclined to deliver lessons which are procedural and reliant on pupils following rules which ignore conceptual understanding.”

Under these conditions’ participants perceived that teachers were more likely to *“stick to a simple activity and the lesson is teacher led board and text book work”*. The impact on identity formation and the mental health of the teacher was also raised as a concern:

“weak subject knowledge undermines you, erodes your confidence and can really have a detrimental impact on your own self-esteem.”

Conversely good teaching was associated with strong, confident teachers in command of a solid knowledge base:

“Teachers with stronger subject knowledge are more motivated and confident. If a student is getting it wrong, they can strip the problem down to its basics to explain it several different ways until the student understands.”

Discussion

Analysis of the data illuminated several themes worthy of further discussion, however, to ensure meaningful dissemination of the findings I have limited the emergent themes to include only participants’ disposition and their attitudes and approaches towards learning specific to the role a perceived deficiency in subject knowledge plays in limiting the development of identity.

According to Shulman (1986) there is ‘a *growth in knowledge of teaching*’ specific to the process of converting subject matter for the purposes of teaching. Commonly known as Pedagogical Content Knowledge, this is a special type of knowledge that only teachers have and is the process where a teacher transforms specialist knowledge of their subject discipline into content suitable for effective pedagogical dissemination (Shulman, 1986, 1987).

But what if, during the process of training, the pre-service teacher perceives that their knowledge is limited, and they do not have enough specialist subject knowledge to transform? What is the impact of a subject knowledge gap on pedagogy, and on the formation of an individual’s identity as a teacher?

While training to teach, individuals encounter many experiences that cause concern, however, analysis of this research identifies that there is a specific type of anxiety around a lack (or perceived lack) of subject knowledge and findings from this study show the impact of weak subject knowledge on a pre-service teacher’s development is significant.

Findings show that if during training the pre-service teacher's subject knowledge is deficient (as perceived by the individual), then their ability to adapt subject matter for the purpose of teaching is compromised.

At the liminal moment, the point when subject matter should become Pedagogical Content Knowledge, if the pre-service teacher's subject knowledge is deficient (perceived or real), this creates a gap in the space where one's identity as a teacher is formed, which has the potential to limit personal development and subsequently restrict the formation of professional identity.

Where a pre-service teacher does not have the knowledge from which to draw, they struggle to know what they are teaching or why they are teaching it. It is this lack of subject knowledge that prevents the pre-service teacher from developing the ability to transform subject matter into pedagogical content in order to make knowledge accessible to a learner. Under these conditions, the pre-service teacher encounters increased levels of emotional anxiety often manifested as an inability to cope. This impacts negatively upon an individual's ability to fully form a strong professional teacher identity and in turn to develop strong self-efficacy. These feelings (of anxiety) have the potential to undermine an individual's confidence, *leading to low teacher efficacy*. Building upon the use of diagramming (which was used throughout during the data collection and analysis phases of this study) Figure 2.0 illustrates the correlation in and between study outcomes.

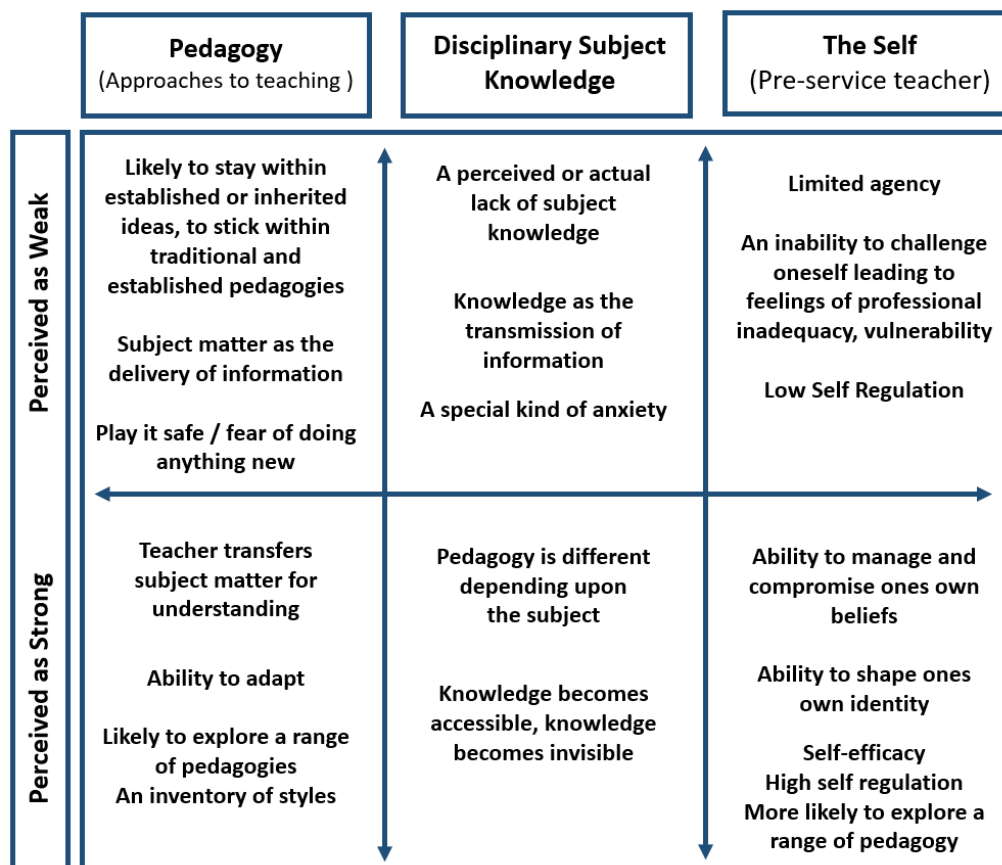


Figure 2.0

The Subject Knowledge Gap: Impact on Pedagogy and Identity

During training, the absence of strong subject knowledge prevents the pre-service teacher from having the fullest opportunity to learn to teach. Where the pre-service teacher maybe

preoccupied with learning subject knowledge, they are unable to focus fully on developing their pedagogical skills as a teacher. This is likely to lead to an inability to innovate, to push personal boundaries, or to take risks, resulting in pedagogical decisions based not on the learning needs of learners, but on their needs to keep safe, to maintain control and manage the behaviour of the class.

As teachers, they are unable to move safely beyond ‘*survival*’ (Le Maistre & Paré, 2010), seek to stay within their comfort zones and situations are created where the teacher seeks to maintain control. In turn, pupils learning is restricted in that it does not go beyond the teachers own prepared knowledge. They prevent themselves from developing and engaging in sound pedagogical approaches to lesson delivery, which subsequently prevents them from delivering high-quality teaching.

Conclusion

Findings from this research show that pre-service teachers’ personal narratives, the meanings they have assigned to past experiences, play a key role in the formation of their professional identities as teachers. Beliefs are shaped by individual sociocultural background, memories, life and work experiences, and in turn professional identities are re-shaped in response to new experiences which are encountered during the process of training to teach.

It is from these beliefs that new meanings are made in light of an individual’s interpretation of current events, but how individual’s approach learning, respond to and subsequently assign meaning to new experiences is inextricably bound to meanings they assigned to experiences experienced in the past.

Shifting identity is a difficult process, and according to Beauchamp and Thomas “*fundamental changes in teacher identity do not take place easily*” (2009:185). Within the context of this study, and of potential interest to those engaged in the development of pre-service teacher education programmes, this is of importance because when encountering difficulties in the classroom, pre-service teachers tend to “*fall back on their traditional memories of how to teach*” based upon experiences from when they were students (Hargreaves, 2010:146).

As analysis of this study’s findings show where an individual perceives they have a gap in their subject knowledge, because their ability to develop fully their own professional identity and self-efficacy is already restricted, under these conditions’ difficulties are amplified.

Weakness in subject knowledge (perceived or real) has been shown to limit an individual’s pedagogical development, which in turn leads to the adoption of constrained teaching styles. Consequently, fewer risks are taken, as pre-service teachers seek to stay within their pedagogical safe space. As such, rather than utilising innovative pedagogy and student-centred approaches, individuals are more likely to adopt teacher-focused teaching methods. In these instances, teaching is more likely to be reduced to the delivery or transmission of knowledge, which according to Trigwell *et al.* (1999) is more likely to result in the learner’s adoption of surface approaches to their own learning.

Within the context of design and technology teacher education, particularly because of the challenges arising from external factors (including curriculum marginalisation, teacher attrition and limited opportunities for subject knowledge enhancement, which is leading to more teachers being required to deliver lessons beyond their areas of expertise), it is desirable that particularly during the early stages of their development pre-service teachers are able to establish a strong sense of self.

This is vital to help ensure that teachers new to the profession are equipped with sufficient pedagogical competence and confidence to enable them to cope effectively with the constant challenges and changes a career in design and technology teaching will inevitably bring.

References:

- Baleghizadeh, S., and Shakouri, M. (2017). Investigating the relationship between teaching styles and teacher self-efficacy among some Iranian ESP university instructors. *Innovations in Education and Teaching International*, 54(4), 394-402.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W. H. Freeman.
- Bandura, A. (1994). *Self-Efficacy- Encyclopaedia of human behaviour*. New York: Academic Press. Vol.4, pp.71-81.
- Beauchamp, C., and Thomas, L., (2009). Understanding Teacher Identity: An Overview of Issues in the Literature and Implications for Teacher Education. *Cambridge Journal of Education*, 39 (2): 175–189. Research Papers in Education 489.
- Beijaard, D., P. Meijer, and N. Verloop. (2004). Reconsidering Research on Teachers' Professional Identity. *Teaching and Teacher Education*, 20: 107–128.
- 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. <http://link.springer.com/article/10.1007/s10798-015-9300-9> Last Accessed 23rd March 2019.
- Bell, D., Wooff, D., McLain, M., and Morrison-Love, D. (2016). Analysing Design and Technology as an educational construct; an investigation into its curriculum position and pedagogical identity. *Curriculum Journal*, Routledge.
- BERA. (2018). *Ethical Guidelines for Educational Research*. Forth Edition. https://www.bera.ac.uk/wp-content/uploads/2018/06/BERA-Ethical-Guidelines-for-Educational-Research_4thEdn_2018.pdf?noredirect=1 Last accessed 22nd March 2019.
- Bleazby, J. (2015). Why some school subjects have a higher status than others: The epistemology of the traditional curriculum hierarchy. *Oxford Review of Education*, 41(5), 671-689.
- British Educational Research Association [BERA] (2018). Ethical Guidelines for Educational Research, fourth edition, London. Available at: <https://www.bera.ac.uk/researchers-resources/publications/ethicalguidelines-for-educational-research-2018> Last accessed 1st March 2019.
- Britzman, D. P. (2007). Teacher education as uneven development: Toward a psychology of uncertainty. *International Journal of Leadership in Education*, 10(1), 1-12.
- Breslin, T. (2016). Subject Hierarchies and the Purpose of Learning – Time to press re-set. Breslin Public Policy, Wednesday 23 November 2016. *The BERA Blog: Research Matters*. <https://www.bera.ac.uk/blog/subject-hierarchies-and-the-purpose-of-learning-time-to-press-re-set> Last Accessed 23rd March 2019.

- Bryant, A., and Charmaz, K. (2007). Grounded theory in historical perspective: An epistemological account. In A. Bryant and K. Charmaz (Eds.). *The SAGE Handbook of Grounded Theory* (pp. 31–57). Los Angeles: Sage.
- Bowden, J. A., and Green, P. (Eds.). (2005). *Doing Developmental Phenomenography*. Melbourne: RMIT University Press.
- Bukor, E. (2015). Exploring teacher identity from a holistic perspective: reconstructing and reconnecting personal and professional selves. *Teachers and Teaching*, 21:3, 305-327, doi: 10.1080/13540602.2014.953818.
- Charmaz, K. (2006). *Constructing Grounded Theory: A practical guide through qualitative analysis*. London: Sage.
- Charmaz, K. (2014). *Constructing Grounded Theory. A Practical Guide through Qualitative Analysis*. London: Sage.
- Day, C., Kington, A., Stobart, G., and Sammons, P. (2006). The Personal and Professional Selves of Teachers: Stable and Unstable Identities. *British Educational Research Journal*, 32 (4): 601–616.
- DES. (1988). Terms of reference of the design and technology working group National Curriculum'. *Studies in Design Education*, 21(1), 4–6.
- Department for Education. (DfE) (2016). *Policy paper: English Baccalaureate (EBacc)*. Updated 24th January 2019. <https://www.gov.uk/government/publications/english-baccalaureate-ebacc/english-baccalaureate-ebacc>. Last accessed 22nd March 2019.
- Department for Education. (DfE) (2019). *Get into Teaching; Bursaries and scholarships*. <https://getintoteaching.education.gov.uk/bursaries-and-funding> Last accessed 22nd March 2019.
- Dey, I. (1993). *Qualitative Data Analysis: A User-friendly Guide for Social Scientists*. London: Routledge.
- Enochs, L. G., and Riggs, I. M. (1990). Further development of an elementary science teaching efficacy belief instrument: A preservice elementary scale. *School Science and Mathematics*, 90(8), 694-706.
- Glasser, B.G. (1992). *Basics of Grounded Theory Analysis; Emergence vs. Forcing*. Mill Valley, CA: The Sociology Press.
- Glasser, B. G., and Strauss, A. L. (1967). *The Discovery of Grounded Theory: Strategies for Qualitative Research*, Chicago, IL, Aldine Publishing Company.
- Gross, M., and Hochberg, N. (2016). Characteristics of place identity as part of professional identity development among pre-service teachers. *Cultural Studies of Science Education*, 11(4), 1243-1268.
- Guskey, T. R. (1998). The age of our accountability. *Journal of Staff Development*, 19(4), 36-44.
- Hargreaves, A. (2010). Presentism, Individualism, and Conservatism: The Legacy of Dan Lortie's Schoolteacher: A Sociological Study, *Curriculum Inquiry*, 40:1, 143-154, doi: 10.1111/j.1467-873X.2009.00472.x

Irving-Bell, D. (2018). *The formation of science, technology, engineering and mathematics teacher identities: pre-service teacher's perceptions*. Lancaster University. <https://doi.org/10.17635/lancaster/thesis/404> Last Accessed 23rd March 2019.

Kelchtermans, G. (2005). Teachers' emotions in educational reforms: Self-understanding, vulnerable commitment and micropolitical literacy. *Teaching and Teacher Education*, 21(8), 995-1006.

Lee, J. C. K., and Yin, H. B. (2011). Teachers' emotions and professional identity in curriculum reform: A Chinese perspective. *Journal of Educational Change*, 12(1), 25e46.

Lee, J. C. K., Huang, Y. X. H., Law, E. H. F., and Wang, M. H. (2013). Professional identities and emotions of teachers in the context of curriculum reform: A Chinese perspective. *Asia-Pacific Journal of Teacher Education*, 41(3), 271e287.

Le Maistre, C., and Paré, A. (2010). Whatever it takes: How beginning teachers learn to survive. *Teaching and Teacher Education*, 26(3), 559-564.

Lindblom-Ylänne, S., Trigwell, K., Nevgi, A., and Ashwin, P. (2006). How approaches to teaching are affected by discipline and teaching context. *Studies in Higher Education*, 31(3), 285–298. doi: 10.1080/03075070600680539.

Lortie, D.C. (1975). *Schoolteacher: A Sociological Study*. Chicago: University of Chicago Press.

Mead, G. H. (1934). *Mind, Self, and Society*. Chicago: University of Chicago Press.

Midgley, C., Feldlaufer, H., and Eccles, J. S. (1989). Change in teacher efficacy and student self-and task-related beliefs in mathematics during the transition to junior high school. *Journal of Educational Psychology*, 81(2), 247.

Paechter, C. (1993). What happens when a school subject undergoes a sudden change of status? *Curriculum Studies*, 1(3), 349–363.

Paechter, C. (1995). Subcultural Retreat: negotiating the design and technology curriculum. *British Educational Research Journal*, 21: 75–87. doi: 10.1080/0141192950210106.

Prosser, M., and Trigwell, K. (1999). *Understanding learning and teaching. The Experience in Higher Education*. Buckingham: Open University Press.

Robinson, K. (2011). *Out of Our Minds: Learning to be Creative*. John Wiley and Sons.

Rodgers, C. R., and Scott, K.H. (2008). The development of the personal self and professional identity in learning to teach in Cochran-Smith, M., Feiman-Nemser, S., McIntyre, J.D., and Demers, K.E. (2008). *Handbook of Research on Teacher Education*, Routledge Handbooks Online.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15, 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57, 1-22.

Staufenberg, J. (2019). AI will soon beat pupils taught knowledge-based curriculum, Schools Week. <https://schoolsweek.co.uk/ai-will-soon-beat-pupils-taught-knowledge-based-curriculum/> Last accessed 22nd March 2019.

Timošćuk, I., and Ugaste, A. (2012). The role of emotions in student teachers' professional identity, *European Journal of Teacher Education*, 35:4, 421-433, doi: 10.1080/02619768.2012.662637.

Trigwell, K., Prosser, M., and Waterhouse, F. (1999). Relations between teachers' approaches to teaching and students' approaches to learning. *Higher Education*, 37, 57–70.

Tschannen-Moran, M., Hoy, A.W., and Hoy, W.K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, 68(2), pp. 202-248.

Tschannen-Moran, M., Hoy, A.W., and Hoy, W.K. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education*, 23(2007) 944-956.

Van Driel, J. H., and Berry, A. (2012). Teacher professional development focusing on pedagogical content knowledge. *Educational Researcher*, 41(1), 26-28. doi:10.3102/0013189X11431010.

Van Veen, K., Slegers, P., and van de Ven, P. (2005). One teacher's identity, emotions, and commitment to change: A case study into the cognitive-affective processes of a secondary school teacher in the context of reforms. *Teaching and Teacher Education*, 21, 917e934

Van Veen, K., and Slegers, P. (2006). How does it feel? Teachers' emotions in a context of change. *Journal of Curriculum Studies*, 38(1), 85e111.

Yuan, R., and Lee, I. (2015). The cognitive, social and emotional processes of teacher identity construction in a pre-service teacher education programme, *Research Papers in Education*, 30:4, 469-491, doi: 10.1080/02671522.2014.932830Y.

Zembylas, M. (2003a). Emotions and Teacher Identity: A Poststructural Perspective. *Teachers and Teaching*, 9 (3): 213–238.

Zembylas, M. (2003b). Interrogating 'teacher identity': Emotion, resistance, and self-formation. *Educational Theory*, 53: 107–27.

Re-designing Design and Technology Education: A living literature review of stakeholder perspectives.

Dawne Irving Bell, David Wooff, Matt McLain



Dawne Irving Bell
Edge Hill University
England, UK
BellD@edgehill.ac.uk



David Wooff
University of Sunderland
England, UK
David.Wooff@sunderland.ac.uk



Matt McLain
Liverpool John Moores University
England, UK
M.N.McLain@ljmu.ac.uk

ABSTRACT

Created following the amalgamation of several individual subject disciplines, in England, design and technology is in decline. Debates about its purpose and position have taken place since its inception but arguably these have not transferred into a rigorous research base. There is a growing body of scholars exploring the field, but with the decline of the subject, so the community working and investigating it is also diminished. Without a strong foundation, the actions of the few may not carry sufficient weight to generate full and meaningful debate that would influence those with the power to change policy on curriculum and lead to innovation.

If we are to have any hope of reversing the subject's deterioration, we must do something bold and significant. While an awareness of the subject's history and its evolution is integral to our understanding of how and why we are where we are, merely reflecting on the past will do little to help the subject move forward. Hence, the principal aim of our research is to explore what a re-designed design and technology could look like. To achieve this, this study draws on different stakeholders' visions of how they perceive the subject's future.

Theoretical underpinning of this work is derived from abductive grounded theory, which aligns with the researcher's individual ontological positions. Drawing together the findings from participants, this paper presents outcomes in the form of a 'living document'. We see this as the first phase in an ongoing study into the future of the subject. Findings indicate a diverse range of opinion relating to the subject's future. Following analysis, outcomes are discussed, and future steps to re-imagine the subject are then explored.

Keywords: Curriculum change, curriculum design, curriculum innovation, design and technology, living document, STEM

Introduction

Design and technology was created following the amalgamation of several individual disciplines, and as an educational construct (Bell et al., 2017) is unique in that unlike its counterpart subjects, for example music, art, science or mathematics, it does not exist beyond the school curriculum.

As a new curriculum subject design and technology was established to serve a very clear purpose, and while in the 30 years since its inception (DfE & WO, 1988) much has changed, the rationale for its creating, to establish a subject that would help to ensure the United Kingdom (UK) would not only maintain its economic global position, but would develop further its industrial and technological capability and capacity, is of no less importance now than it was then.

However, in practice the subject's vision has not ever been fully realised (Barlex, 2017), and in England design and technology is in serious decline. Discussion about its purpose and position have taken place since its creation, but the outcomes of these debates have not transferred into a rigorous research base which could have helped to establish the subject's as one of integral value within the curriculum.

Currently there are a small body of scholars working to explore this field, but coupled with the subject's erosion, the community within which investigations may be conducted is also diminished (McGimpsey, 2011; Miller, 2011; Harris & Wilson, 2003). Without a strong foundation from which to build the actions of the few may not carry sufficient weight to generate full and meaningful debate which may serve to funnel into the ears of those with influence and power to influence policy and hence initiate change.

If there is to be any hope of reversing the subject's decline, we need to do something significant. While an awareness of the subject's history and its evolution is integral to our understanding of how and why we are where we are, reflecting on the past will do little to help the subject move forward.

Hence, considering the future of design and technology, it is from this position, that our interest has been stimulated and we explore the role and purpose of design and technology from the perspective of maintaining design and technology as a school curriculum subject, within an era of political and economically driven change. Therefore, framed from this perspective, the principal aim of this research is to investigate what a re-designed design and technology could look like. To achieve this, this study draws on different stakeholders' visions of how they perceive the subject's future and elicits participant responses to the following questions:

What is design and technology's fundamental purpose; why should it exist? and irrespective any barriers, what should a re-imagined design and technology curriculum 'look like'?

Context

As previously stated, while an awareness of design and technology's history is integral to our understanding of why we are where we are, revisiting the past will achieve little in terms of moving the subject forward. However, to provide a context for this paper this next section will outline, briefly, our beliefs in relation to the subject, its background and the reasons for its underdevelopment, before moving to review recent commentary from members within the community about the subject's future.

Ontologically, our position begins with the contention that because of the nature of design and technology, it has and always will endeavour to keep up to date with technological and economic advances in society, and as such it is and will always be in a constant state of flux.

While this curricular flexibility, which has been an underlying feature of the subject's role in the school curriculum since inception is essential to ensure the subject equips future generations with essential skills, knowledge and understanding to develop both technological capability and confidence, this manifests as a fluid knowledge base, which makes it markedly different to other curriculum subjects. For example, mathematics where the content and knowledge base has not changed significantly for many years.

Drawing upon the theoretical work of Bernstein (1971a, b), who argues that the school curriculum is dominated by subjects which are well defined and have highly classified bodies of knowledge which largely remain consistent over time we believe this, is in part, the reason why design and technology has constantly had to justify its importance within schools' curriculum (McLain et al., 2019, 2018; Bell, 2015; Bell et al., 2017).

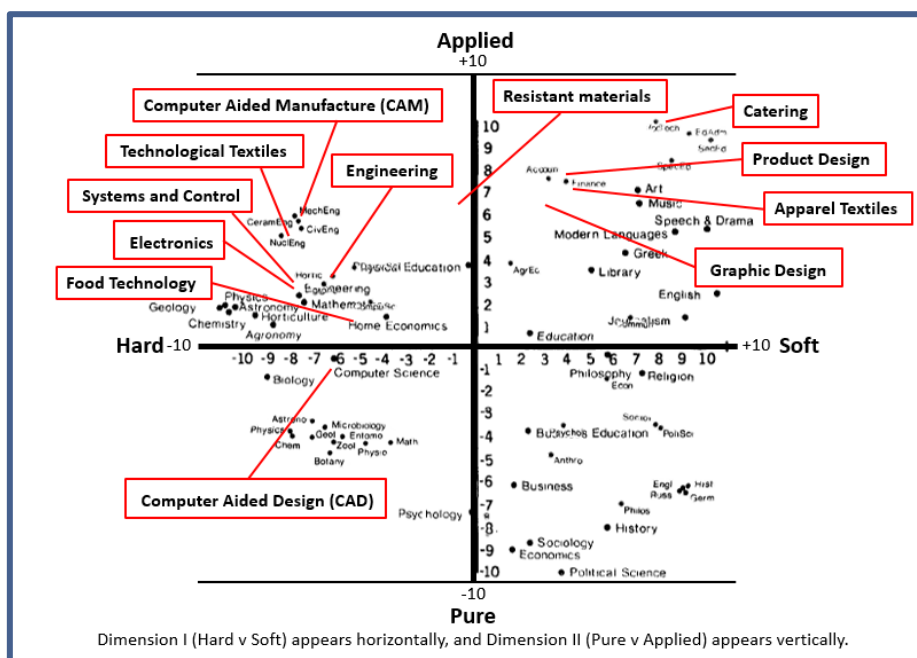


Figure 1
Knowledge territories within design and technology (Bell, 2015)

Positioned from this perspective, when coupled within Biglan's (1973) work which explores the characteristics of subject matter in different academic disciplines, when compared to the more strongly framed and classified subjects, which include mathematics and science, design and technology has, and will always have difficulty in conforming to such 'tight' criteria because of its need to constantly embrace new technological innovations (Figure 1).

As a result, the subject is perceived as having 'weak epistemological roots' (DfE, 2013, p.234), which when positioned within the current knowledge focused curriculum (Gibb, 2016, 2017), combined with a weak research base from which the subject itself may be defined, and indeed defended, it is no wonder that design and technology has consistently failed to establish itself

as a subject of real value, and one that is essentially integral to a child's comprehensive education.

Literature

While literature has illuminated the subject's failings (Miller, 2011), and establish reasons for the issues and challenges faced (Bell et al., 2017), while there has been much discussion within the subject's community (D&T Google Group, 2019) these debates remain unpublished, and hence have not been supportive in developing a solid body research informed by evidence from which the subject may be defended.

Rather than undertaking a radical revision of the subject, in their think piece Barlex and Steeg (2017) focus on rebuilding design and technology. The rationale being that they believe the original vision for the subject, outlined within the Parkes Report (DfE & WO, 1988) remains compelling. Whilst we do not disagree and would concur that the rationale behind the subject's original inception is still persuasive, drawing upon the 'building' metaphor our argument is that in order to build, or indeed re-build, one requires a firm foundation from which to start. In this regard our perspective differs.

Also, while there can be no doubt that the economic imperative remains, and we firmly believe that as a subject discipline design and technology has much to offer, in positioning this work we must also be mindful that in mapping future developments against the subject's original intentions, current directives make clear that the school curriculum has moved on (Gov.uk, 2014). Therefore, this may prove likely to be a painful and potentially damaging exercise. As a subject community we need to be open to the view that other curriculum areas, such as computer science, where there has been significant fiscal investment in recent years (DfE, 2015), may be perceived to be of more value in meeting the country's current technological and economic needs. From this perspective design and technology may no longer retain the currency it once had within the current political and economic agenda.

Irrespective of the material area this paper seeks to align individual participants perspectives and identify those aspects which all perceived as being fundamental to the subject's core. Hence, with a view to the creation of a stable platform from which to instigate further debate, the focus and rationale for this paper is to present stakeholder perspectives from which the re-design the subject may begin.

Methods and Methodology

Theoretically underpinned by social constructivism, which aligns with the authors' individual epistemological and ontological positions, this study adopts a relativist paradigm and we recognise the subjective experiences of multiple realities for the participants, and ourselves (Guba 1981, 1990).

As such methods adopted this work are derived from an approach informed by constructivist grounded theory (Charmaz, 2006; 2014). This approach was selected because it allows for the concurrent gathering and analysis of data which enables outcomes from earlier research phases to set the purpose and direction of the next.

Embracing an abductive methodology, this combines both inductive and deductive theory generating procedures which was adopted because it encouraged the consideration of all possible theoretical outcomes, rather than forcing one to emerge. Strauss and Corbin (1990) and Corbin and Strauss (2008), discuss this method as an effective approach to theory building, whereby the researcher may mix grounded theory with other methodologies and apply existing insights and experiences to the phenomena under study.

Prior to participation the aims and purpose of the study were explained to participants and informed consent obtained, and ethical practices outlined by the British Educational Research Association (BERA, 2018) were adhered to throughout.

In selecting participants respondents were chosen for their abilities to provide rich and varied accounts of their design and technology experience as possible (Geertz, 1973). Considering the future of design and technology the key questions focused on the participants responses to the following question:

What is design and technology's fundamental purpose? Why should it exist? Please try to think '*blue skies*', so irrespective any barriers, what should design and technology look like?

The study elicited responses from ten participants, who were approached on the basis that each was a key stakeholder within the UK design and technology community. Care was taken to ensure participants reflected a diverse mix of age, gender and design and technology subject discipline and included experience serving design and technology teachers, voices from industry and members of the Initial Teacher Education (ITE) community. Consultation also invited commentary from the Design and Technology Association (D&TA) and colleagues from former organisations including the National Association of Advisers and Inspectors in Design and Technology (NAAIDT).

Data gathering and analysis

Using methods advocated by Bryant and Charmaz (2007) and Charmaz (2014), while gathering data care was taken to ask the same single open, exploratory question. Verbal and written discourse with follow up email discourse were used as the primary research tools to gather empirically grounded data relating to the perceptions, understanding, and lived experiences of participants. Where applicable face-to-face interviews were undertaken in accordance with procedures advocated by Bowden and Green (2005), and all data (irrespective of the collection mechanism) was recorded and transcribed verbatim, with care taken to accurately record responses in order to avoid misrepresentation.

Given the diversity of responses, revised from our original intention (which was to present the findings in the form of a living conversation) in order to help assure anonymity and so as not attribute a single ideology to an individual participant, in practice, adopting an approach similar to phenomenography, we pooled the transcripts (Åkerlind, 2005; Bowden and Walsh, 2000), and present the data as conceptual findings which are not aligned with or to individual participant responses. Within phenomenography analysis draws out categories of description and defines outcomes spaces in levels of understanding (Marton, 1994; Marton & Booth, 1997). In a similar way, we pooled the data in order to identify both the similarities and differences between the way in which participants perceived the phenomena under study.

As researchers we understand that different people experience the same 'thing' in different ways, hence during the process of analysis, and mindful of the difficulty of setting aside one's own assumptions and pre-conceptions (Prosser, 2000), to help avoid bias and ensure that a second order perspective was maintained, the strategy of 'bracketing' (Bruce et al. 2004; Ashworth and Lucas 2000; Dunkin 2000) was adopted. Having pooled the data, during analysis and in the process of coding we adhered to procedures advocated by Charmaz (2014).

Presentation of data

With analysis focused on how theoretical aspects of the study relate to what is happening in practice, representative of the complexities found within design and technology in the current schools' curriculum environment, drawn from the diversity of responses, this paper seeks to present individual participant perspectives together in the form of a living narrative to create a coherent whole from which future work can evolve.

In presenting the data, determined to echo the fluid nature of our subject discipline, we draw upon the powerful concept of the 'living document', through which we seek to not only share for dissemination these findings, but to actively encourage open and continuous collaboration to extend and grow this work within and beyond the design and technology subject community.

According to Shanahan (2015) the limitations of the traditional research paper are well known, and advocating a move toward living documents, where a single article exists for a single piece of research, utilising technology, Shanahan claims that it is time to move beyond the '*now obsolete print model*' of research articles, and truly embrace the freedoms that online publications allow. In their work Wambeke et al. (2017) advocate the use of this approach to help ensure that theories in use remain relevant.

Hence, through our adoption of this approach as we seek deliberately to present our findings and analysis as a 'work in progress', informed by emergent thinking and as such open to continual editing and revision by the community in order to enable real evolution and growth in search of the subject re-imagined.

Initial coding and analysis of the data were identified and refined, with participants responses relating to design and technology activity falling into three broad central themes, ideation, realisation and critique (Figure 2):

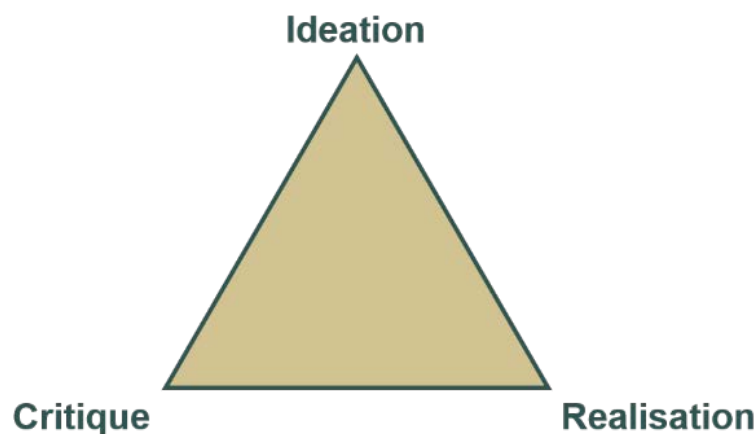


Figure 2
Design and technology activity: ideation, realisation and critique

The terms ideation, realisation and critique have been adopted in place of the more common designing, making and evaluating, in order to 'disrupt' the dialogue and historicised understanding of the subject. We also acknowledge the potential for a perceived hierarchy and separation between the three; instead, considering them as interacting in a dynamic

manner, each having an inherently symbiotic relationship within design and technology activity, and a pedagogue of transformation (Morrison-Love, 2017).

Critique

In this category (Figure 3) we present for consideration participant responses that illuminate the subject as one where knowledge for action transcends procedural knowledge (Kimbell, 2018; Kimbell et al., 1996).

Within this context technology is explored as a tool to serve human needs in order to develop a better society for all citizens.

Through the exploration of authentic activity, contextualised within society, the focus would address issues including (but not exclusive to) sustainability and product evaluation, well-being and human rights, always in consideration of the impact and consequences technological innovations may have. Advocating above all that individuals develop ways of understanding the complexities of life, are open minded in the generation of solutions, give meaning and through their ideas' connections to the past. Be mindful of the present, and with an eye on the future, be cognisant of the notion that just because you can does not always mean that you should.



Figure 3: Critique

Ideation

Within ideation (Figure 4) design and technology is conceived as a subject which transcends traditional material areas and goes beyond a defined body of knowledge and skills. Here the focus is the creation of authentic opportunities for learners to engage in speculative questioning and deferred judgement, always being encouraged to consider alternative technological solutions to human centric problems.

To engage in non-restrictive, open and playful design; to be imaginative and creative in developing design capability. To become fluent in the connection and external communication of ideas, and to explore ways of thinking. To explore and engage in the creation of 2D and 3D ideas and visualization, developing prototypes and models, and it is not always necessary to realise a complete artefact. To recognise and acknowledge the folly in creating unneeded solutions.

In doing so develop individual agency and autonomy, build resilience and an ability to handle uncertainty with confidence. A discipline which moves beyond the bounds of a traditional curriculum, which in practice, irrespective of the original intention, the focus inevitably becomes about doing and making stuff.



Figure 4: Ideation

Realisation

There is something unique about making, the ability to manipulate and control a material to create an artifact. Within this category (Figure 5) participants cited the importance of the feel of the material and bringing a product into being, with the skills required to create a physical response to a given question being cited as a transformative pedagogy.

In addition to developing autonomy and building confidence, essential skills which participants cited included interpreting instructions, working to a set brief, the development of eye hand co-ordination, manual dexterity and fine motor skills. Within this outcome there were a number of tensions. The first was in relation to a subject 'not pretending to design'. Here responses questioned the need to design before embarking upon the manufacture of a product. This objectification of technology was supported by a number of responses which indicated that working to develop a prescribed set of material related knowledge and skills in order to create a high-quality take home product was itself sufficient to be stand-alone discipline. Related to this a further tension arose with regard to the development of skills, with some questioning the value in relation to the increased use of technology, for example Computer Aided Design (CAD) within the subject.

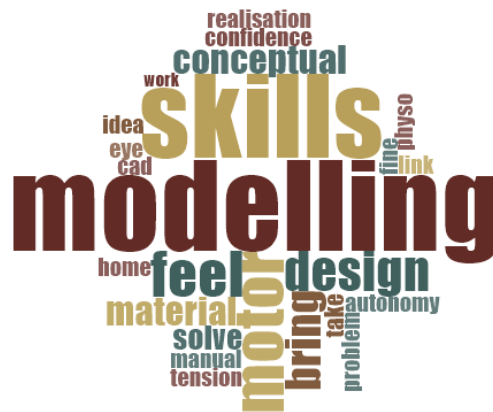


Figure 5: Realisation

Discussion and conclusion

While research has, as was expected, brought to the fore a breadth of opinion in relation to the content of design and technology, analysis has elicited some areas of ‘non-negotiable’ common ground as well as tensions. In addition, consider features of what might design and technology’s curriculum intentions emerged and have been coded as knowledge, experience and dispositions (Figure 6). In this section of the first iteration of this living research informed document, we seek to align these outcomes within the current educational and political context, and with consideration of the wider global setting.

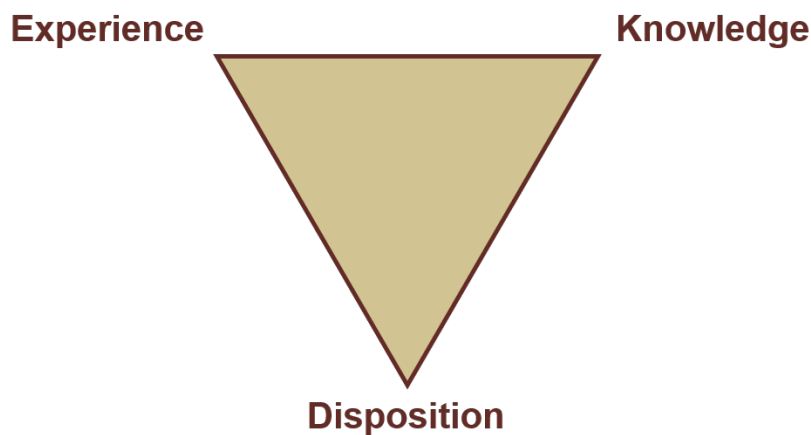


Figure 6

Design and technology curriculum intentions: experience, knowledge and disposition

Curriculum intentions

Spanning all participant responses, a series of desirable **dispositions** for learners emerged (Figure 7). Participants felt strongly that the subject should seek to develop attributes including team building, communication (including the extrapolation of ideas) and collaboration. Resilience, and the development of an ability to take informed risks and engage in ‘proud failures’ was also cited by participants. Integral to these notions appeared to be the desire to encourage the emergence of a curriculum which developed dispositions that align within the

domain of so-called soft skills. Particularly within the context of this study, where design and technology itself is categorised as soft, we believe that it is important to note that the interpretation of language, particularly around the use of hard and soft subjects, which implies that one is harder and therefore more important than another is grossly misleading. This notion also applies therefore to the development of so called 'soft skills', which within the context of technological innovation and a potential move away from a knowledge-based curriculum are becoming increasingly more important (Staufenberg, 2019) and this is a trap which we must avoid falling into.

A second emergent category, **experience**, relates to what learners 'do' (i.e. what they experience) within the subject, what is important to know. Participant responses include reference to authentic approaches to problem solving, context and an awareness of human needs and wants within a technological society. An additional strand explored by some participants valued the working knowledge of materials alongside the development of physical skills including manual dexterity, although this relationship (between materials knowledge versus developing manual skills) as articulated below was also illuminated as a dimension of tension within the data.

The third category, **knowledge**, extends beyond the boundaries of the subject and relates to participant perceptions of a broader body of knowledge. Dimensions of knowledge considered were, by the learner in relation to political and global agendas, knowledge for action and situated knowledge, within the context of other subject disciplines. The nature and role of knowledge has been written about and discussed by a number design and technology authors, including in relation to the interaction between mind and hand during ideation (Kimbell, 2018; Kimbell et al., 1996) and the complex relationship between conceptual (knowing that) and procedural (knowing how) knowledge (McCormick, 1997). In addition, design and technology has historically acknowledged drawing on bodies of knowledge from other subjects (DfE, 2013).

The triad represented in Figure 6 reflects some of the contemporary and competing perspectives on curriculum. Young (2008) promotes the notion of so-called powerful **knowledge**, currently promoted by political decision makers in England (Gibb, 2017), whereas others focus on **experience** (Biesta, 2014) or aims (Reiss and White, 2013), where aims include skills and **dispositions**, as more cogent drivers for curriculum design. The emergence of these 'codes' in the findings highlights potentially useful and disruptive tensions with which to explore design and technology, without the distorting effect of imposing a single curriculum theory, focus on limited intentions. This is particularly relevant in the current context in England, where there is a shift in the Office for Standards in Education (Ofsted) inspection framework for schools away from teaching and learning and towards curriculum intent, implementation and impact (2019).



Figure 7
Design and technology curriculum intentions: learner dispositions

Tensions

Commonly held tensions focused around political drivers, fiscal demands and constraints and the academic versus vocational debate. Within the responses half of the participants made some reference to design and technology's vocational heritage, and as a vehicle through which young people could study technology in order to help to meet the needs of a contemporary work force. During the process of analysis, it became clear that there are tensions between the concept of a discipline which moves beyond specific materials or a set body of knowledge, and one which advocates traits which could be perceived as being more aligned with established subject origins and traditions. Where this encultured versus transcended view of materials occurred, tensions tended to be crystallised around material areas which aligned with participants individual subject disciplines. Given that previous inspection findings have concluded that design and technology teaching of design was less effective than of making, with pupils "often spending too much time on superficial work" (Ofsted, 2001, p.1) one might be forgiven for assuming that the tensions between designing and making might have been resolved. However, materials in design and technology appear to continue to be a point of contest (Figure 8).



Figure 8
Design and technology curriculum tensions

A missing tension?

There can be no doubt that design and technology has much to offer the STEM agenda, and a number of commentators (Banks & Barlex, 2014; Barlex, 2009; Bell 2016), including the National subject association (D&TA, 2017) have discussed the relevance of design and technology as a subject for the 21st century within this context. Many advocate that in order to maintain its influence, design and technology must demonstrate the effective use of science and mathematics (Barlex, 2007) and from this perspective we were anticipating that a significant proportion of responses would reflect this view in that in order to help create a firm foundation for any future iteration of the subject to thrive an alliance with STEM would be desirable.

However, despite a breadth of literature which would support this notion, irrespective of the participants background or material area during analysis we were surprised that in discourse responses made little or limited reference to STEM.

First phase reflections

Unsurprisingly findings present a diverse range of opinion relating to the subject's future. However, in seeking to attain some semblance of cohesion rather than continue to focus on the differences, analysis has sought to disentangle the data and bring to the fore common

insights and understandings; with themes from the nature of design and technology **activity** (ideating, realising and critiquing) and its curriculum **intentions** (knowledge, experience and dispositions). Not to mention, **tensions** created by the subject's relationship with materials (metals, polymers, textiles woods, etc.) and the STEM agenda.

Only through illumination of the mutual ground, those key elements and features which all agree are fundamentally integral to the subject, can we begin to move forward.

To note this is not in any way to say that diversity is not desirable. For clarify, in seeking to identify commonality, within the context of this paper we mean the identification of shared aims, and make clear that we firmly believe that in order to move forward as a unified community, it is essential that we celebrate and promote the interdisciplinary diversity of the subject as a strengthen; and the diversity of the individual disciplines must no longer be allowed to manifest as division as perhaps externally it has been perceived. Division, internal or external, perceived or real, will serve no purpose other than only to further weaken the subject's position.

Rather than seeking to reclaim, re-name or re-frame, throughout we have sought to avoid a focus on repairing the subject, which we believe would potentially result in a make do and mend approach to the development of a revised curriculum. In moving this 'think piece' forward, working again with stakeholders it is intended that the proposed next step subsequent to the dissemination of these initial findings will be to formulate a consensus of opinion that leads to a vision of the subject re-imagined and what, in practice for those charged with delivery, that may look like. In the spirit of the living document approach which has been adopted for this work we welcome contributions from the community, and invite the open critique, adaption and development of this paper. In turn drawing from those new, additional perspectives it is our intention to continue to maintain communication, and to keep the conversation growing.

In thinking about the future of design and technology, whatever form it may take, we propose a working model for discussing the tensions between activity and intentions (Figure 9). In particular, we challenge the community to transcend current and historic understandings of design and technology.

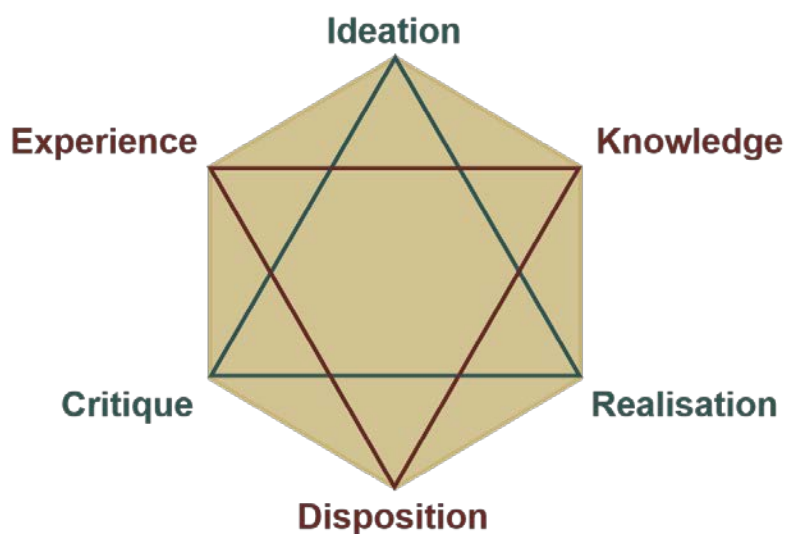


Figure 9

Challenging current and historic understandings of design and technology: a working model

Acknowledgement

We would like to thank all of those who responded to our call for their perspectives on the future of design and technology education. Without the community's full engagement this starting point for further discourse would not be possible, hence the support and encouragement received from the community has been very much appreciated.

References

- Åkerlind, G. (2005). Learning about phenomenography: Interviewing, data analysis and the qualitative research paradigm. In J. A. Bowden & P. Green (Eds.), *Doing developmental phenomenography*. Melbourne: RMIT University Press.
- Ashworth, P., & Lucas, U. (2000). Achieving empathy and engagement: A practical approach to the design, conduct and reporting of phenomenographic research. *Studies in Higher Education*, 25(3), 295–308. doi:10.1080/713696153.
- Banks, F. and Barlex, D. (2014). *Teaching STEM in the Secondary School: helping teachers meet the challenge*. Abingdon: Routledge.
- Barlex, D. (2017). Design and Technology in England: An Ambitious Vision Thwarted by Unintended Consequences. In M.J. de Vries (ed.), *Handbook of Technology Education*, Springer International Handbooks of Education, DOI 10.1007/978-3-319-38889-2_11-1
- Barlex, D. and Steeg, T. (2017). Re-Building Design and Technology In the secondary school curriculum, Version 2, A Working Paper. Available at <https://dandtfordandt.wordpress.com/> Last accessed 31st March 2019.
- Bell, D. (2015). Design and technology; educational fallacy or principal exponent of school-based STEM activity? Poster session presented at Annual Conference for Research in Education: Controversies in Education: Problems, Debates, Solutions. Seventh Annual Education Conference 8th and 9th July 2015, Edge Hill University.
- 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. <http://link.springer.com/article/10.1007/s10798-015-9300-9> Accessed 2nd April 2019.
- Bell, D., Wooff, D., Mclain, M., and Morrison-Love, D. (2017). Analysing Design and Technology as an educational construct; an investigation into its curriculum position and pedagogical identity. *Curriculum Journal*. pp. 1-20. ISSN 0958-5176
- Bernstein, B. (1971a). On the classification and framing of educational knowledge, in Young M.F.D.(Ed). *Knowledge and Control: New directions for the sociology of education*. London: Collier MacMillan, 47-69.
- Bernstein, B. (1971b). *Class, codes, and control*, vol. I. London: Routledge & Kegan Paul.
- Biesta, G. (2014). Pragmatising the curriculum: bringing knowledge back into the curriculum conversation, but via pragmatism. *The Curriculum Journal*, 25(1), 29-49. doi:10.1080/09585176.2013.874954

Biglan, A. (1973). The characteristics of subject matter in different academic areas. *Journal of Applied Psychology*, 57(3), 195–203.

Bowden, J. A., and Green, P. (Eds.). (2005). *Doing Developmental Phenomenography*. Melbourne: RMIT University Press.

Bowden, J. A., & Walsh, E. (Eds.). (2000). *Phenomenography, qualitative research methods series*. Melbourne: RMIT University Press.

British Educational Research Association [BERA] (2018). *Ethical Guidelines for Educational Research*, fourth edition, London. Available at: <https://www.bera.ac.uk/researchers-resources/publications/ethicalguidelines-for-educational-research-2018> Last accessed 1st March 2019.

Bruce, C., Buckingham, L., Hynd, J., McMahon, C., Roggenkamp, M., & Stoodley, I. (2004). Ways of experiencing the act of learning to program: A phenomenographic study of introductory programming students at university. *Journal of Information Technology Education*, 3, 143–160.

Bryant, A., and Charmaz, K. (2007). Grounded theory in historical perspective: An epistemological account. In A. Bryant and K. Charmaz (Eds.). *The SAGE Handbook of Grounded Theory* (pp. 31–57). Los Angeles: Sage.

Charmaz, K. (2006). *Constructing Grounded Theory: A practical guide through qualitative analysis*. London: Sage.

Charmaz, K. (2014). *Constructing Grounded Theory. A Practical Guide through Qualitative Analysis*. London: Sage.

Corbin, J., and Strauss, A. L. (2008). *Basics of Qualitative Research: Techniques and procedures for developing Grounded Theory*. Thousand Oakes, CA: Sage.

D&TA (2017). STEM into action with D&T: London Schools Project. <https://www.data.org.uk/for-education/secondary/stem-into-action-with-dt/> Last accessed 2nd April 2019.

D&T Google Group (2019). <https://groups.google.com/forum/#!forum/dt-itt-tutors> Last accessed 31st March 2019.

Department for Education and Science and Welsh Office (DfE&WO). (1988). *National curriculum design and technology working group interim report*. London: HMSO.

DfE (2015). *£3.6 million for technology experts to train computing teachers*. <https://www.gov.uk/government/news/36-million-for-technology-experts-to-train-computing-teachers> Accessed 31st March 2019.

DfE (2013). *National curriculum in England: framework for key stages 1 to 4*. London: Department for Education Retrieved from <https://www.gov.uk/government/publications/national-curriculum-in-england-framework-for-key-stages-1-to-4>.

DfE (2011). *The Framework for the National Curriculum: A report by the Expert Panel for the National Curriculum review*. (DFE-00135-2011). London: Department for Education

Retrieved from <https://www.gov.uk/government/publications/framework-for-the-national-curriculum-a-report-by-the-expert-panel-for-the-national-curriculum-review> Last accessed 1st April 2019.

DfE (2014). The national curriculum for England to be taught in all local-authority-maintained schools. <https://www.gov.uk/government/collections/national-curriculum> Last accessed 31st March 2019.

Dunkin, R. (2000). Using phenomenography to study organisational change. In J. A. Bowden & E. Walsh (Eds.), *phenomenography*. Melbourne: RMIT University Press.

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

Gibb, N. (2017). *The importance of knowledge-based education: School Standards Minister speaks at the launch of the 'The Question of Knowledge'* [Press release]. Retrieved from <https://www.gov.uk/government/speeches/nick-gibb-the-importance-of-knowledge-based-education>

Gibb, N. (2016). *Nick Gibb: what is a good education in the 21st century?* [Speech]. Retrieved from <https://www.gov.uk/government/speeches/what-is-a-good-education-in-the-21st-century>

Guba, E. G. (1981). Criteria for Assessing the Trustworthiness of Naturalistic Inquiries. *Educational Communication and Technology*, 29(2), 17.

Guba, E. G. (1990). The Alternative Paradigm Dialogue. In E. G. Guba (Ed.), *The Paradigm Dialogue*. London: SAGE.

Harris, M., & Wilson, V. (2003). Designs on the Curriculum? *A review of the literature on the impact of Design and Technology in schools in England*. Retrieved from <https://webarchive.nationalarchives.gov.uk/20090204141420/http://www.dcsf.gov.uk/research/data/uploadfiles/RR401.pdf> Last accessed 1st April 2019.

Kimbell, R. (2018). Constructs of Quality and the Power of Holism. Paper presented at the *PATT36 Research and Practice in Technology Education: Perspectives on Human Capacity and Development*, Athlone Institute of Technology, Co. Westmeath, Ireland. <http://terg.ie/index.php/patt36-proceedings/> Last accessed 1st April 2019

Kimbell, R., Green, R., & Stables, K. (1996). *Understanding practice in design and technology*. London: Open University Press.

McCormick, R. (1997). Conceptual and Procedural Knowledge. *International Journal of Technology and Design Education*, 7(1), 141-159. doi:10.1023/A:1008819912213

McGimpsey, I. (2011). *A Review of Literature on Design Education in the National Curriculum*. Retrieved from London: <https://www.thersa.org/discover/publications-and-articles/reports/a-review-of-literature-on-design-education-in-the-national-curriculum-report> Last accessed 1st April 2019.

McLain, M., Irving-Bell, D., Wooff, D., & Morrison-Love, D. (2018). Cultural and historical roots for design and technology education: why technology makes us human. Paper presented at the *PATT36 Research and Practice in Technology Education: Perspectives on*

Human Capacity and Development, Athlone Institute of Technology, Co. Westmeath, Ireland. <http://terg.ie/index.php/patt36-proceedings/> last accessed 1st April 2019.

McLain, M., Irving-Bell, D., Wooff, D., & Morrison-Love, D. (2019). *How technology makes us human: cultural and historical roots for design and technology education*. Manuscript submitted for publication.

Miller, J. (2011). *What's Wrong with DT?* Retrieved from London: <https://www.thersa.org/discover/publications-and-articles/reports/whats-wrong-with-dt> Last accessed 1st April 2019.

Marton, F. (1994). Phenomenography. In T. Husen & T. N. Postlethwaite (Eds.), *International encyclopaedia of education*, (2nd ed., Vol. 8, pp. 4424–4429). Oxford: Pergamon.

Marton, F., & Booth, S. (1997). *Learning and awareness*. Mahwah, NJ: Lawrence Erlbaum Associates.

Morrison-Love, D. (2017). Towards a Transformative Epistemology of Technology Education. *Journal of Philosophy of Education*, 51(1), 23-37. doi:10.1111/1467-9752.12226

Ofsted (2019). *Education inspection framework: overview of research* Retrieved from <https://www.gov.uk/government/publications/education-inspection-framework-overview-of-research>

Ofsted (2001). *Ofsted Subject Reports, 1999-2000: Secondary Design and Technology*. London: Ofsted.

Prosser, M. (2000). Using phenomenographic research methodology in the context of research in learning and teaching. In J. A. Bowden & E. Walsh (Eds.), *Phenomenography*. Melbourne: RMIT University Press.

Reiss, M., & White, J. (2013). *An Aims-based Curriculum: The Significance of Human Flourishing for Schools*.

Shanahan, D. R. (2015). A living document: reincarnating the research article. *Trials*, 16(1), 151.

Strauss, A.L., and Corbin, J. (1990). *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Newbury Park, CA: Sage.

Wambeke, B., Barry, B., and Bruhl, J. (2017). Teaching Model as a Living Document, American Society for Engineering Education Annual Conference and Exposition, Columbus, OH. DOI: 10.18260/1-2--28924. Available at: <https://www.researchgate.net/publication/318661764> Last accessed 10th March 2019.

Young, M. (2008). From Constructivism to Realism in the Sociology of the Curriculum. *Review of Research in Education*, 32(1), 1-28. doi:10.3102/0091732X07308969

Analysing ‘values’ in collaborative development of D&T education units.

Ritesh Khunyakari



Ritesh Khunyakari
Tata Institute of Social Sciences
India
ritesh.k@tiss.edu

ABSTRACT

The paper reports, a part of, the findings from a larger study that involved teaching, learning and research to engage postgraduate students in developing Design and Technology Education (DTE) units for school students. Four DTE units have been analysed to understand the role of values in play across different phases of design-and-make experience. The analysis suggests an emergent interplay of values in thought and action, through a generative discourse on negotiating ideas, constraints and resources. The study proposes the need for examining ‘values-in-context’ of their practice. Such an exploration helps in understanding how values play a crucial role in shaping design-and-make experiences, and ways in which they can be made explicit, supported or challenged during the process.

Key words: deliberative curriculum, design and technology education, design-based research, values-in-context

1.0 The evolving landscape of DTE in India

Design and Technology Education (DTE) is yet to establish its identity as a subject within the Indian school curricula. This has been the case even though Indian educational system offers scope to choose courses specialising in “design” and “technology” at the post-secondary and higher education levels. In India, DTE is a school subject, exclusively in schools that follow the International Baccalaureate (IB) curriculum. Even in such spaces, confusion around what exactly needs to be taught and learnt remains prevalent. The pervading tension about the nature and scope of DTE in India, can be traced back to subject antecedents and socio-political, historic forces of influence.

1.1 Antecedents and socio-political forces influencing technology education in India

In India, art and handicrafts were one of the earliest traditions of influence that lay emphasis on hands-on work, very similar to the trends in other countries across the globe (de Vries, 2018). Historically, in the Indian context, technology has been envisioned to address some

deep-rooted societal problems and initiate socio-cultural transformation (Arnold, 1946/2000). However, in academic or technical programmes of higher education, that deal with design and technology, the discussions related to the nature and scope of technology or its relation with other disciplines are rather scant. Historically, art and handicrafts have been merged under the extra- or co-curricular activities in the school curriculum. Besides serving the purpose of enabling expressions, art and craft are considered as means to develop sensitivities to culture and aesthetics, and to learn techniques for skilful representations. As an alternative to the colonial approach to education, Mahatma Gandhi proposed Basic Education, emphasising the principles of self-reliance and dignity of labour, through productive work (HTSS, 1938). However, the restructuring of school as a self-supporting, economic entity was critiqued and after independence, this imagination lost steam. Kothari Commission (1964-66) recommended 'work experience' as a school subject to promote hands-on learning (Gol, 1966). However, the scope of this subject hardly extended beyond knowing technical principles of working and repair of everyday artefacts such as a bicycle, replacing a fused bulb, making paper toys, etc. In the later years, Ishwarbhai Patel Committee report (1977) proposed productive work to be called Socially Useful Productive Work (SUPW), which later translated into community service (NCERT, 1979). The scope included activities such as, cleaning school spaces, visiting rural localities to offer help, etc. Effectively, the role of hands-on activities to strengthen cognitive capacities and connect to the sociological dynamics was eventually lost. Another asymmetrical acknowledgement of hands-on learning grew as Vocational Education, which offered scope to students to pursue certification or diploma courses in technical trades (Natarajan & Chunawala, 2009). In some schools, students could opt for a vocational education stream instead of an academic (regular) stream, post seventh grade (age 12 years). Although the curricular reform intended to absolve the sharp contrast between the ascribed role of intellectual and manual work, the vocational education stream ended up accentuating the differences and reinforced the social hierarchies.

Amidst the confusion related to school subjects and activities within it, the discipline of science was instrumental in making India shift from a traditional, orthodox society to a modern society striving towards scientific and technological progress. Arnold (1946/2000), a historian of science, noted,

“Railways, irrigation canals, dispensaries and hospitals, the printing press, the cinema and the motor bus had a material and cultural influence that reached far beyond the Western-educated middle classes. Despite the resistance that at times confronted technological innovation, diets and birthing practices, ideas of gender and community, race and nation, all in various ways and by different routes came to feel the impact of scientific, technological and medical change. Science by 1947 had come to assume a public importance, a social impact and a cultural resonance inconceivable at the start of the colonial era.” (p213)

In reckoning the relation between science and technology for the contemporary times, Basu (2015, p.145) coined 'technological temper' to capture the features of technoscience. This acknowledged technology as (a) ontologically prior to science, (b) involving actionable knowledge, (c) embodying design and values, and (d) following the role of Harm and Value Principles in accepting or rejecting technoscience.

More recently, there has been a growth in play resources that encourage students to construct and build artefacts based on template-driven, re-organisation of raw materials. These allow scope for tinkering by offering practical experiences with materials outside the laboratory settings through 'Do-It-Yourself' (DIY) kits. Informal design-and-make experiences also happen through short orientation camps, such as, nature, astronomy or literary clubs; and exposure camps, such as, pottery, making scientific toys or artefacts from waste materials. While the social space is laden with such informal ways of influencing life-activities of learning for students, formal experiences to hands-on learning are rather limited in number and scope

(breadth of disciplines being covered). Science projects allow some scope for devising new and innovative solutions to societal problems, but they are conceived as 'out-of-school' activities (Bhattacharyya, 2004). The wide range of informal and formal exposure to hands-on experience nurture curiosity, but does not strength cognitive capacities or sociological imagination. The convergence of opportunities involving hands-on learning within the existing curriculum is needed to make learning meaningful. Such an envisioning begets the larger questions concerning values *of* and *in* learning.

Amidst these influences of antecedents, technology education in India has remained a *pot-pourri*, bearing a confused identity with little of distinctive characterisation as a school subject or a specific area of learning (Choksi, Chunawala & Natarajan, 2006). This socio-historic, political discourse in India towards assimilating a relation with technology education helps us realise that there has been an ever-changing, interlacing with technology that often seeped into school curricula in rather disparate and non-cohesive ways. Any effort towards envisioning ideas of technology education needs to be situated within these contextual realities and tensions so as to make meaningful contributions to practice.

2.0 Conceptual groundings for the study

The research can be conceptually located within the situated learning paradigm (Lave and Wenger, 1991) which envisions learning as an integral and inseparable aspect of social practice, and which happens through dynamic interactions between material, people and activities embedded in the social, cultural and historical context. The study follows a Design-Based Research (DBR) methodology. According to Barab & Squire (2004), DBR is a naturalistic, process-oriented, iterative, tangible design which works in complex social settings. Another significant characteristic of DBR, that aligned with our research approach, was that "the learning environments DBR studies are often developed by the researchers who are studying it and advancing theoretical claims about it." More importantly, DBR deals with complexity by iteratively changing the learning environment over time, collecting evidence of the effect of these variations and feeding it recursively into future designs (Brown, 1992). These features are also characteristic of the kind of interplay between the various phases of our study. The DTE units developed in the study were field-tested and involved a design-and-make experience. A design-and-make context motivated individuals to find alternatives or solutions towards addressing some real-life problem by drawing upon their prior knowledge and negotiating meanings through participation in a collaborative activity (also noted by Rowell, 2004). Design problem solving involves working with ill-structured problems with no definite solutions and where sketches, drawings and modelling constitute the language of 'design' culture (Cross, 2006). The interplay of values manifested in the entire process of study and are also the point of focus in this paper.

2.1 Strengthening 'values' in technology education

In the literature (Hardy, 2015; Halstead & Taylor, 2000; Layton, 1993; Eggleston, 1992), discussion on the role of values in education seems subtly omnipresent, particularly in the discourse concerning aims of education and accountability in education. While problematising the issues related to curriculum, Kumar (2009) brought our attention to a central question of "what is worth teaching?". He suggested two routes for addressing the question. The first consisted of deciding the worth of what we want to teach, in the view of learner's needs and abilities, and the second related to the intrinsic value of the content. Further, he argued that the first route could be reliably addressed through conscious attention to psychology and pedagogic approaches. The challenge of a deliberative curriculum manifests itself in the second route, which acknowledges that educational form of knowledge cannot be solely determined on some intrinsic characteristics of knowledge but also a conscious addressing of the symbolic associations that shape the perceptions of knowledge (whose knowledge, socio-political, historical and cultural dynamics in relating to knowledge) in society. Clearly, the question itself and proposals for addressing it, both seem to emanate from the standpoint of 'values' and seek critical attention in designing and implementing a curriculum.

In the context of technology education as a school subject, scholars have appealed to different levels of values in play. The most fundamental level includes the evolutionary advantage that humans gain from the capacity to invent (Calder, 1968). In the contemporary context, values relate to the immediate environment (Vyas, 2009) as well as the larger socio-economic, political, and cultural landscape within which processes of design-and-make are embedded (Basu, 2015). At a broader level, values involve making conscious judgements or decisions within the constraints, considerations and purposes to which human action is directed. The values form 'the criteria people use to select and justify actions and to evaluate people (including the self) and events' (Schwartz, 1992). Prime (1993) argues that, equipping children with technological capabilities is dangerous without delving into discernment of the values associated with them. The framework on values, proposed by Prime, includes biological needs, coordinated social interaction, and survival and welfare needs of groups. These categories have been further classified as (a) personal, (b) social and economic, and (c) political, cultural and environmental. Several scholars (Trimingham, 2008; Coles & Norman, 2005; Holdsworth & Conway, 1999; Breckon, 1998) have further enriched the framework by adding newer categories as, *moral*, *technical* and *aesthetic* values. Drawing our attention to the classical discourse between knowledge and values in the literature on technology education, Pavlova (2005, 2002) argues for a framework which includes the role of values in thinking *about* and *within* technology. She noticed that an emphasis on the intrinsic (technical or economic) values manifested in a technocratic understanding of technological knowledge, which ought to be balanced with a focus on instrumental or non-intrinsic (moral, competence-based) values, and the latter needed to be researched. This paper maintains that an analytical introspection of practice would offer insights into the characteristics and the nature of values within technology education. A practitioner's standpoint would help understand the expression of values and enable conceptualise the relation with technology education in more concrete and nuanced ways.

3.0 Objectives of the study

The larger investigation aimed to:

- encourage groups of student teachers to identify a technological design problem and develop a suitable DTE unit to engage schools students,
- understand the challenges, constraints and opportunities that confront student teachers in thinking, planning and implementing ideas in DTE, and
- reflect on the nature of support required for building a conceptually embodied, contextually relevant and practice-informed perspective on technology education.

The specific objective included developing an understanding of the role of values in the pedagogic experiment being studied. This objective is addressed through the following research questions:

Which are the set of values that primarily emerge from the context of developing DTE units?

How does the interplay of values manifest itself in thinking about learning objectives and students' engagement?

During the development of units, which values do participants incorporate in making choices about what to teach?

What are the conditions and contexts in which values gained an explicit influence governing decision-making into teaching and learning?

To examine these questions, the study follows an analysis of four cases involving participants engaged in designing and field-testing the DTE units.

4.0 Description of the study

The study reported here is part of a larger investigation which integrated teaching, research and development. The participants in the study were 34 student teachers, pursuing a two years Masters of Arts in Education from an established university, who opted for an elective course on DTE. The author, a teacher-researcher, taught this course to the participants in 2017-18. This is the only teacher education programme in India which offers DTE as an elective course to prospective teachers and teacher educators. The course teaching familiarised participants with the discipline of technology education through readings on nature, philosophy, influences, curricular, pedagogic and assessment concerns in DTE.

As part of the course, participants were encouraged to be a part of a pedagogic experiment which included design, development and trials of DTE units for Indian school students. The participants worked in 11 groups of 3-4 individuals to develop and field-test a DTE unit to develop an understanding of concerns and considerations in translating their teaching plan into practice. The DTE unit included designing an artefact, which they considered as “low technology” followed by field-testing the unit with school students (henceforth, students) of a neighbourhood school. The process of development and field-testing used the ‘collaboration and communication-centred model for pedagogy’ (Khunyakari, 2015; inspired from Kimbell, Stables & Green, 1996). The teacher-researcher provided several activity sheets that elicited participants’ ideas about the context, content, activities and assessment. These activity sheets served as scaffolds, inviting participants to think about the various aspects that form an integral part of the pedagogic model. Participants’ reported their experiences of field-testing through reflective writing.

The research design used in this study resonates with the ‘understanding’ model of researching, proposed by Hammersely (2011). The understanding model of research recognises that there can be no absolute givens in an enquiry and that the knowledge produced reflects the available cultural resources. According to him, understanding implies a process of ‘making something one’s own, cognitively speaking: to know it from the inside.’ (p134). This study is an effort to understand the place of values in DTE by drawing upon experiences of struggles, challenges and triumphs in developing and field-testing the units shared by student teachers in several phases. An initiative into collaborative designing a DTE unit is a simultaneous act of envisaging practices that are contextually, culturally suitable and demand critical reflections that feed into conceptualisations. On one hand, the constraints of implementing ideas are limited in terms of time, and possible flexibility of conducting trials across diverse settings. On the other hand, the study provided a critical, peer mass to think and reflect through ideas which meet the dual demands of being suitable within the curricular context and being pedagogically sound. This paper argues that the unique positioning of participants engaged in thinking about a curricular domain and its practice, afforded desirable synthesis of an organic growth of curricular activities by practitioners, a feature that Batra (2005) and Kumar (2009) argued has been missing in the Indian curricula and policies. At the same time, the study design allowed scope for participants to shift in the dynamic role of teachers-as-researchers, a knowledge perspective gaining wide acknowledgement (Kincheloe, 2003). The immersion of participants in the context of formal, academic, institutional learning posits certain prospects and constraints, which we need to be aware of as we discuss the insights from study.

4.1 Participants

This paper discusses four cases, with each group consisting of three participants. The participants represented an eclectic mix of individuals with different educational exposure in terms of their domains of prior study at the undergraduate level (for example, computers, elementary education, english, history, management, media studies, physics, etc.). All participants had little or no exposure to developing teaching units. Since the group formation was voluntary, gender fair distribution across all groups could not be maintained. Participants

from all the four cases chose to work with middle school students (Grades VI or VII) from the government schools in the vicinity. Each group planned the field-testing of their DTE units in break time or after the school hours, to avoid intervening with the regular school proceedings. These cases were selected for their relevance to everyday contexts (sanitation to map-making), variety in manifestations of technology (artefacts, processes and systems) and appeal concerning the social relevance of technology.

4.2 Data sources and Process of analysis

Each of the groups maintained a digital portfolio, which included participants' responses to the activity sheets. The activity sheets acted as scaffold to direct participants' attention to specific issues and enabled tracking of the transition in ideas (refer Table 1). The reported experiences of designing and field-testing a DTE unit by each group, formed the unit of analysis. The work of each group constitutes a case, which is followed through the process of development and implementation. Data analysed for this paper includes introspective and reflective writings of participants, activity sheets which had records of participants' thinking, discussions, and technical drawings from their portfolios.

The process of data analysis involved annotating and memoing the write-ups submitted by groups. This helped in identifying patterns which indicated an overarching influence of values in decision-making at various points of the study. The pattern matching was followed by a microscopic analysis of DTE unit, developed by each case, to identify evidences for the

Table 1: Scaffolds for groups during different phases of developing DTE units

<i>Phase</i>	<i>Activity sheet (Activity#Sheet#)</i>	<i>Group / Individual</i>	<i>Detail of tasks (T) within each activity sheet</i>
0	Introduction (A1S1), Self-information sheet (A1S2), Initiation (A1S3)	Individual/ Group	T1: Names of team members; T2: Brainstorming ideas
1	Contextualising the idea (A1S3)	Group	T1: Framing an appropriate context for technological design problem solving
2	Planning the design (A1S4)	Group	T1: Thinking about needs and purposes; T2: Estimating materials and resources; T3: Thinking learning
3	Modelling & Anticipating the outcome (A1S5)	Group	T1: A step-by-step anticipation of procedure for making; T2: Planning learner deliverables and assessing them; and T3: Reflecting on design idea, improvisations and self-assessment
4	Realising an idea through 'making' (A1S6)	Group	T1: Visiting design changes and process of making
5	Evaluating & Communicating (A1S6)	Group	T1: Thinking assessment involving learners and evaluation of the product
6	Reflection (A2S1)	Individual	T1: Process of design-and-make; T2: Assignment as a means to learning

influence of values. A cross-case analysis was used to identify features which were similar and distinctive across cases. The subsequent section on analysis will first discuss insights

derived from patterns of engagement across participant groups. This is followed by a detailed discussion of each case, with a focus on the emergent 'values-in-context'.

5.0 Analysis and Findings

The analysis is organised in two parts. Part A discusses the engagement with values during the developmental phases and practice of DTE units for each of the four cases. Part B discusses insights drawn from patterns of engagement as elicited through a comparative analysis of cases, with a focus on the four cases selected.

PART A: EXAMINING EXPRESSIONS AND CONTRIBUTIONS OF VALUES

For each case, a brief description about the DTE unit developed by group participants is presented. An effort is made to discuss some salient evidences of 'values-in-context' observed in various phases of designing and field-testing of the DTE units. The closing note consolidates interpretative insights that help in assimilating the role of values in DTE.

CASE I: MUSICAL INSTRUMENT FOR COMMUNICATION

This group encouraged students to develop a musical system by exploring materials around them. The cogent system of communication so developed would be used for exchanging encoded messages. The group struggled in making students find the relevance and authenticity in doing the task. Along with an exploration of materials in immediate environment, concerns about teaching physical concepts remained at the heart of practice, as was also expressed in the plan of assessment. The idea of developing a communication technology began with human capacities to discern frequencies from varied materials but its relevance was guided by the value consideration of safety (refer Excerpt 1). The emphasis on developing an informed understanding of concepts related to sound and communication, such as,

Various types of material can be used to produce different kinds of sounds. Human beings are good at perceiving different frequencies. (Human beings perceive sounds between the frequency of 20Hz-20,000Hz.) It might be possible to encode meaning into different frequencies of sounds made from varied types of material. This encoding can help individuals, in a variety of circumstances, to communicate. One such circumstance can be one where presence of danger needs to be communicated in a way that doesn't catch attention of the perpetrator of danger.

frequency, pitch, sonorosity, and coding capacity continued to persist and inform the way their DTE unit would be contextualised for school students.

Excerpt 1: Values for rationalising potentials of a technological design idea (A1S3G1) [Code A1S3G1 represents Activity 1, Sheet 1, Group 1]

The Alien's Jugaad context is basically a problem situation within a story, wherein two aliens have descended upon the earth. They are scheduled to present a dance performance to humans, but it is only at the last moment that the alien who is assigned the dance realizes he is unprepared. Now, to save face in front of humans, he asks his alien friend to help him by instructing certain dance moves to them from backstage live. There are two things to keep in mind: 1. The helping alien is backstage, and neither can see the other, 2. They're aliens. Even though they can produce sounds, they don't know the concept of language as we know it. The students were asked to divide themselves into pairs and assign the roles of the Helping Alien and the Performing Alien amongst themselves in each pair. They were then given 15 minutes to devise a means of communicating simple dance moves for the performance. The communication was to be strictly non-verbal/non-visual. There were to return after 15 minutes and demonstrate their language in front of rest of the class.

A value-laden approach to thinking about technology manifested in the way technological design problem-solving was 'contextualised' and 'presented to students' by the participants. Beginning with a straight-forward, technical context (see Excerpt 1), the participants chose to use story context with alien characters to underscore the distinction between the cryptic and secretive aspects of communication from the oral and symbolised modes used in everyday communication (cf Excerpt 2).

Excerpt 2: Values in appropriating context (A2S3G1)

The possibility of communicating without using verbal language was considered as a feature unique to their design. There seemed to be a correlate between operationalising a construct, thinking about a pedagogic activity and ways to assess outcomes from the activities. For instance, what sonorosity implies, how it is to be evaluated with respect to materials explored, and the

Sonorosity: A successful production of a distinctly high pitch/low pitch sound by both learners in a pair (using identical or different kinds of objects) will indicate they have understood the correspondence between material and sound. It will also be evident from how one pair's product produces a louder, more audible sound, as compared to another.

Retrospectively, they can be asked to reflect- "Which other material could have given me a louder and more distinct sound than what I used?"

kind of activities planned to explore and interpret the idea of sonorosity (see Excerpt 3).

Excerpt 3: Technical values in conceptual understanding and assessment (A1S7G1)

As evident in excerpt 3, value of material properties are significant not just while designing learning but also in assessing learning. Earl (2003) asserts that given the history of schools, the intimate and inextricably intertwined imagination of assessment is revolutionary and often discomforting for the teachers. In addition to assessment *of* and *for* learning, she emphasises the need to integrate assessment *as* learning, where students monitored own learning and use the feedback to adapt. Students routinely reflect on their work, relate it to prior knowledge, master the skills involved and make judgements about how they can capitalise on what they have done already. Such a self-directed, reflective and regulatory process of metacognition informs assessment *as* learning. The metacognitive purpose of developing an understanding about 'nature of language' manifested through the different phases of developing and implementing DTE units. The manifestations translated into emphasis on connecting learning concepts with experiences, emphasis on collaborative processes involving encoding and exchange of messages, and criteria developed to assess learning.

CASE II: SANITARY KIT WITH A PERIODS CYCLE INDICATOR

Unlike the first case, the group members in Case II had a different rationalisation derived from a deep-seated social concern. The group aimed at encouraging girl students to develop their sanitary kit, which included self-made sanitary napkins and a periods cycle indicator to keep a track of their menstrual cycle. The experience of designing efficient napkins from easily available resources had a dual transformative agenda: one, of building technical knowledge;

and two, using technological understanding to challenge the narrow perceptions and social

Rani: Creating awareness. Menstruation, in many cultures is seen as a taboo. This stigma is created due to the cultural, religious and social misconceptions and still exist to the present time. Firstly, girls, need to be educated about the essence of understanding the human body and the hormonal changes it goes through. Secondly, once the girls (who go through menstruation) are targeted, boys can be also taught and can be taught about what a female body goes through and to empathize. Thirdly, this unit can be taught by explaining:

- 1) The biological attributes and changes in the body
- 2) The history and understanding of how the existing kits such as pads, tampons and menstrual cups have come into existence.
- 3) Learning about the various materials and designs that were used previously.
- 4) Analysing why it did not work and how it has evolved over a period of time.
- 5) Activity: designing using materials such as cotton

We would set some conditions for designing this unit which are:

- a. We are teaching and **all girls school** in a rural or an economically and socially backward urban area where direct access to menstrual products are difficult.
- b. Target grades are 7th or 8th standard as this is the time when most girls have started menstruating.

taboos.

Excerpt 4: Value-steered decisions influencing planning and field-testing (A1S3G2)

In this group, social and personal values together shaped the decision-making about the suitability of a technological design problem. The participants' decisions involved not just appropriating the nature of content or decisions at critical junctures involving material resources used, but it related to foresight about how the unit would be received by students. The tension is evident in an activity sheet (A1S3G2) where Aniket (pseudonym) contemplated about the choice of problem situation for their DTE unit. He said, "Coming up with a unit involving going against a taboo, creating awareness and at the same time making students create something is, I feel, a challenge and risk worth taking". In this context, risk-taking which often is recognised as a personal value judgement, gains a social character in light of a consideration that compares acceptance and opportunities afforded. The centrality of a value-grounded stance in rationalising the need, the activities and learning goals of DTE unit (see Excerpt 4) reveal the salience of values in decision-making. Concerns for ecology, social

contexts of engagement and the experiential values were evident in participants' reflections

Students' ability to engage and explore a topic can be catalysed with the use of materials....Our artefact was the idea of raising awareness to the process menstruation and personal hygiene by understanding the efforts to make one's own sanitary pad... By getting a hands-on experience of artifacts by the students, while they explored the concept, aided in deeper understanding in the value of the physical nature and social process that revolves around menstruation. This symbolic representation of a sanitary napkin aided in steering conversations dig deeper into discussions leading to the sharing of experiences, opinions and ideas about menstruation. Additionally, it also helped us understand the nuances involved in teaching design as a subject and involving ourselves in a student's thought process for the entire design-make-appreciate section. ...We also draw inspiration from the Work and Education National Curriculum Framework of 2005. It highlights the education system to be majorly Brahmanical giving dichotomizing work and theory and in the present education system. It reduces work education as mere recreational activities and certifies or validates the theoretical or book based knowledge. It proposes a '*work centered pedagogy*' in which knowledge construction does not alienate the students in creating a social change, participation in productive work to building values at times of need or crisis and promote use of multiple skills, and, a space to engage with artisans, workers and professionals involved in work (NCERT 2007).

on field-trials (refer Excerpt 5).

Excerpt 5: Reflection on learning possibilities afforded by their DTE unit (A2S1G2)

The above discussion brings out the role of values in making judgments about what is worth teaching and concerns that need to be built into the pedagogic discourse. Integrating value concerns in the design and development of an artefact, help in recalling Gandhi's ideas (noted by Kumar, 2009) about the *functional* and *symbolic* salience in basic education, which emphasised development of productive skills through schooling. The functional purpose involved a conscious effort to relate school to the processes of production in local milieu, thereby, achieving self-reliance. The symbolic purpose related to elevating sociology of school knowledge, by placing knowledge developed by and associated with oppressed groups or lower of Indian society, namely; artisans, peasants and cleaners. This unit seems to address both the functional and symbolic salience by keeping, designing an artefact, at the centre of the process.

CASE III: MAP MAKING FOR NAVIGATION

This group's choice of a suitable technological design problem worth pursuing rested on the possibility of engaging with students' cognitive capacity of representation. Diverse mix of activities characterised the structure of their DTE unit on map-making which involved making maps of neighbourhoods, puzzle-solving, extending mapping to elicit and address gender-stereotypical viewpoints about human bodies, and relating to cultural contexts of use of maps for navigation, discoveries of routes to America and India and the use in GPS-directed cabs.



Figure 1: Context map emerging from a collective exploration of the notion of 'maps'

The participants considered possibilities that aligned with and constituted map-making as DTE unit. These included introducing students to the idea and purpose of cartography, interactive social experiences in mapping, cognitive aspects related to imagination, and even maps of human body to sensitise students about body shaming. Interestingly, values seemed to inform their thinking about 'why' and 'how' the diverse mix of ideas be integrated in their DTE unit. For instance, inclusion of an activity that invited students to represent their immediate neighbourhood on ground using easily available resources as stones, jute rope, dried leaves, etc. followed by an activity on treasure hunt allowed for making a shift from familiar, immediate environment to puzzle-solving by decoding an abstracted visualisation that uses symbolic and codified language. As values of conscious assimilation of surroundings were highlighted, the need to operate on the assimilated knowledge and their representations were also underscored. Similar such translations of value-informed perspective informed the designing and practice of the DTE unit. An activity of eliciting students' ideas about map highlighted the socio-political purposes of use of maps, such as *caste map* to represent caste groups living in an area; *DJ map* to trace travel of a professional DJ, and *Charminar map* of a monument of symbolic and historic relevance (see Figure 1). The value-oriented thinking is also ripe for furthering innovative ideas that have relevant bearings. For instance, drawing on cues from the teacher-researcher, the participants thought of maps for blind, deaf and dumb people. Interesting ideas on use of materials such as, toothpick to puncture cardboard to create a projective surface or using stitches on paper to provide a relief feature allowing exploration through the sense of touch emerged. The value considerations of social inclusion permeated in using visuospatial abilities for developing maps for the differently-abled.

The instrumental function of values in scoping as well as situating activities from across domains is evident in this unit. The range of activities included were value-driven attempts towards building an associative understanding of ideas that go beyond just the immediate purpose of maps to represent reality or its utility for navigational purposes. Instead, value considerations in designing DTE units open to students opportunities to simultaneously think about implicit ideas (of boundaries, socio-political delineation, etc.) and invite them to contextualise their innovation (maps for blind, deaf and dumb).

- a) Children's access to artefact and familiarity with it, because we felt that within a class it is very important that each learner identifies with the artefact and possess some amount of rudimentary understanding of functions of the artefact
- b) The frequency of its use as it allows the student to bring to the class the diverse situations where they have seen the artefact being used
- c) Essential nature of its use so that the learner possesses clarity of the primary purpose of its use.
- d) The diversity in design of the available broom/wiper variants on the market. When students share their experiences of differently designed brooms/wipers which are used with the same end-goal, then it might encourage them to incorporate additional features in the design of their product
- e) Simplistic design as students would have the confidence of undertaking the "make" activity and would not feel it is overwhelming and beyond their capacities. It would also help them develop simple design sketches in the initial stages of the module
- f) Multiple components on closer inspection, because each component of the wiper/broom has a special function. So students would be able to study material properties while trying to construct a functional artefact
- g) Consideration of the users, as it could bring out the existing social differences of caste, class and gender stereotypes.

CASE IV: BROOM FOR EASY CLEANING OF INACCESSIBLE SPACES

The group selected their artefact keeping in mind a range of values: socio-historic, economic, ergonomic and aesthetic values (refer Excerpt 6). The problem context evolved from participants' design to the field-testing phase, which incidentally involved a negotiation of values among participants and the students.

Excerpt 6: Considerations in developing the technological problem context (A1S3G6)

The participants encouraged students to sketch their design solutions and make models. Inclusion of modelling allowed exploration of materials and resources to develop a 'proxy' realisation, which involves metacognition (noted by Gilbert, 2005). The act of modelling

involved mediation and reciprocation that supported students' visualised ideas, as noted in

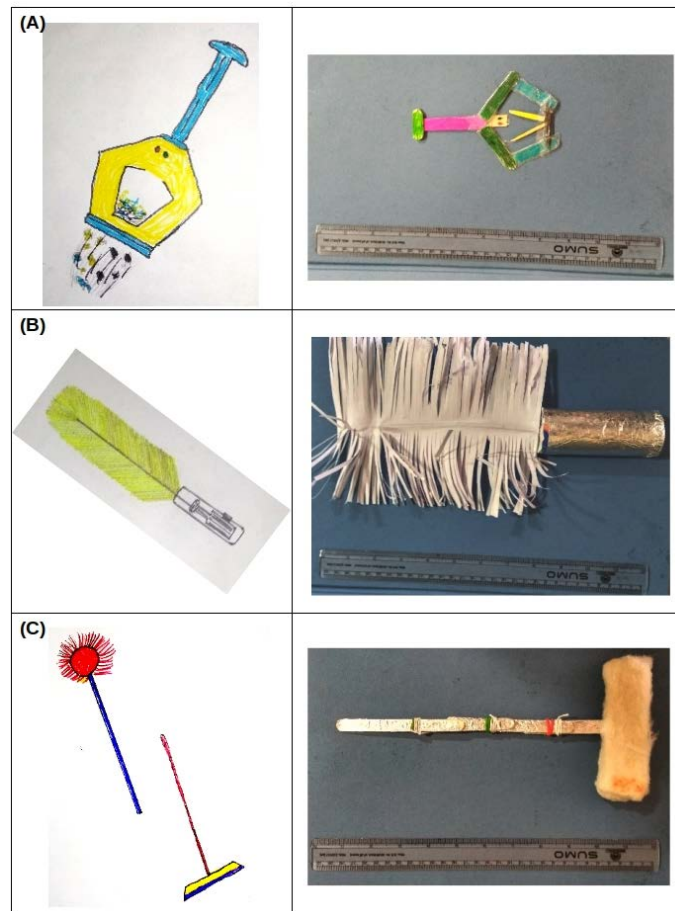


Figure 2: Design drawings and models by students

the choice of resources for constructing the models (refer Figure 2).

The DTE unit developed by participants got refined as they interacted with students. One of the evidences for evolution was the movement of problem context itself from designing 'efficient' cleaners that aid dusting rooms, wet floors, cleaning walls, etc. to devising a multipurpose, cost-effective, cleaner for wet and dry surfaces, that can easily reach corners. In other words, the design challenge experienced a shift from developing a 'hypothetical ideal' to a 'realisable solution around a practical concern' with greater specificity. The pragmatic value consideration emerged from discussions of participants with students and got internalised in the detailing of problem context itself.

A complex interplay of values in developing the problem context and later refining it during the field-testing informs us that conscious attention to values in the context of practice can help develop an understand *about* and *within* technology (Pavlova, 2005). The meditational role of values in designing and tailoring DTE unit by providing students' opportunities to extend their understanding and develop creative ideas leads to nuanced appreciation of technology.

PART B: INSIGHTS FROM PATTERNS OF ENGAGEMENT

The following sections bring to discussion some patterns observed across cases.

5.1 The governing role of a *prior* knowledge and early impressions

A comparative analysis of the list of potent technological, design problems across cases revealed a wide range (3 to 125 ideas) and variety (products, processes and systems) of ideas explored and discussed. Groups of participants were invited to think of artefacts/processes/systems that represented “low technology”. Incidentally, the technological problems chosen by participants suggests an uncanny alignment with the perception about “low technology” prevalent among the Indian middle school students (reported in Khunyakari, 2008). This concurrent trend points towards (a) a commonality in appreciation of technology and therefore a greater likelihood in relating to ideas; and (b) a hope for developing wider sensibilities in building a comprehensive understanding of technology. Table 2 provides a comparative summary of four cases discussed earlier. For most groups, from the collective set of ideas generated through brainstorming, the choice of an idea for developing a DTE unit happened to be the one which either temporally preceded in emergence (5 out of 11 groups) or was the most recent (4 out of 11 groups). Drawing from the literature on memory and cognition (Mayo & Crockett, 1964), the principle of “primacy” or “recency” seemed to influence the development of a DTE unit. Concomitantly, an appeal to immediate, context helped in situating the DTE unit.

5.2 Crucial mediation of ‘values’ in decision-making

Value-based decisions surfaced as participants rationalised their ideas and worked towards framing the technological design problem context. The process of framing required participants to foresee whether the idea would appeal to students and provide opportunity to foreground their stance with regard to technological engagement. For instance, in Case I (refer Table 2) the context is more than just an ensemble of artefacts that could produce aesthetically pleasing sounds. The unit demanded making and encoding sounds to create a private language of communication, thereby capturing a *technical* as well as a *symbolic* function. It was observed that the choice of design problem was consistently inspired from an assessment of the immediate context, identifying the limitations of the artefact-in-use and a desire to extend its instrumental purpose. For instance, the musical instrument was designed for building a system of communication (an extended purpose), using the knowledge of sonorosity and resonance. In Case II, the group felt the need to break the social taboo prominent in the Indian context by making people aware of the menstrual cycle of women. The group unpacked the process of making a sanitary pad using locally available resources. Like Case II, in Case IV, the participants foregrounded the need to develop social sensitivity by developing a multi-purpose artefact that maintained cleanliness, a marker of a profession involving people from lower caste in Indian society.

The nature of values that gain prominence in decision-making and also the emphasis on kind of values seemed to shift through the various phases of designing, planning, making and evaluating. For instance, in almost all the groups, maintaining reasonable costs of making, emerged as a consideration at the making phase of their unit (see Table 2). Further, some values became more prominent during the field-testing of the unit. For instance, in Case III, values such as cultural assimilation of knowledge represented through maps, use of accessible materials to exercise representational value of mapping real objects onto a different space to capture everyday reality such as home, path to school or reaching locations, etc. gained prominence at the making stage. It seems that values manifest at certain crucial junctures of designing, making and evaluating. Further, an analysis of participants’ decisions reveals critical role of a ‘cognitive value’ in developing design ideas, choice of materials and extension of knowledge generated. The inter-animation of values shaping choice of a low technology and pursuing it as DTE unit, in the context of collaborative decision making requires further examination.

5.3 Tapping ambitious goals through transgression of concept boundaries

It was observed that participants developed ideas that often transgressed immediate conceptual content and brought to the fore ideas of social relevance. For instance, in Case I, the intended purpose of developing musical instrument went beyond the expressive understanding of communication to encoding meaning and providing alert calls in situations of danger. Similarly in Case III, the purpose of map making incorporated body mapping to not just extend significance of the idea of representation of reality but to sensitise students to mapping body parts, which addressed gender concerns. These conscious boundary crossings

Table 2: Comparison of four cases

	Case I	Case II	Case III	Case IV
	Musical system	Sanitary kit	Map-making	Multi-purpose broom
Composition	1B+2G= 3P	2B+1G= 3P	3G=3P	1B+2G=3P
Ideas listed as “low tech”	7	22	10	3
Ranking of idea	2	1	1	3
Other best ideas	Broom & Cooling system	Designing kurtas & sarees	Football studs, Magnifying glass, Umbrella, Paper bags	Clipper style ball-point pen, Plastic fittings within air-conditioners & refrigerators
Developed context	Materials to produce sounds, encode meaning & help communicate, especially in danger	Social & biological processes around menstruation; history of menstrual hygiene, diff. materials used	Experience, Story, Puzzle, Social, Historical, Cultural and Psychological	Problems in different cleaning situations (scenarios), dignity of labour, caste
Initial considerations	Encoding meaning, Communication in danger	Socio-economically backward urban area or rural area, class 7/8 students	Sensitising about human body by mapping bodies - addressing body shaming	Looking for different solutions for wet & dry cleaning, caste & dignity
Emerging considerations	Cost of making, nature of language	Cost & resource diversity	Cost	Cost
Concepts foregrounded	Pitch, Sonorosity, Collaboration, Nature of language	Biological attributes & changes in body, historical understanding, variety of materials & designs, Evaluating efficiency & evolution of ideas	Immediate neighbourhood, decoding map as puzzle solving, Mapping body, cultural discoveries & GPS by cab drivers	Multipurpose - wet & dry cleaning, structure-function attribute to materials & form, Addressing caste hierarchies

allowed participants to explore and consolidate content, ideas and possibilities across domains.

In a certain manner, the transgression allowed for connecting knowledge, skills and meaning-making. The outcomes of transgression often involved a conscious process of translating ideas of worth into activities that can be concretely pursued in the practice of DTE unit. For

instance, in Case II, the participants explored a range of materials which could absorb blue starch solution effectively. Their activity invited students to experiment with the blue starch solution and check the penetrating (absorption) potential of the materials from which diapers were made. The activity also invited students to take cross-sections of diapers to compare a qualitatively visible difference in efficiency of various materials used. The question of value begets significance while locating learning that negotiates a dialogue between, what has been described by Eggleston (1977) as, the 'received' and 'dynamic' perspectives on curriculum. The 'received' perspective is derived from an *a priori* view of knowledge, whereas the 'dynamic' perspective places knowledge in a sociological context and inquires into its legitimacy.

6.0 Conclusions and way forward

This research reports analyses the emergence and contribution of values in the process of designing and reflecting on DTE units among prospective teachers and teacher educators. First, the study suggests that there is an absence of a comprehensive framework in the literature, to support an analysis of emergent values in the process of design-and-make. Research in technology education focuses on an investigation of ideas, attitudes and perceptions about technology to inform the design of learning experiences aimed to expand notions about technology (Khunyakari, 2008). Although literature highlights the need for building from an understanding of pupils' perceptions so as to develop an informed perspective on shaping the learning experiences, research on how this could be operationalised for practitioners, remains rather bleak. The pedagogic experiment reported involved pursuing a design problem perceived as "low technology" and developing a DTE unit around it, by drawing upon nuanced understanding of aspects concerning nature of technology. The freedom to select and pursue a DTE idea created ownership among the participants and rendered insights about the contextualised nature of design problems. The process of development helped participants in transiting from conceptualisation to actualisation, which afforded opportunities to study values in context.

Different kinds of values gain precedence in choosing and contextualising different technological design problems, for instance, ideas in Case I and II initiated from personal interests (of a secret communicative system) and social values (creating health consciousness and sensitivities), respectively. Case III drew upon multiple value strands, political (mapping bodies and neighbourhoods), symbolic (gendered identities) and technical (supporting differently-abled). Case IV addressed the culturally ingrained value perception of broom and cleaning, and it being a multipurpose, effective solution. Values emerged and evolved through the different phases of development, field-testing and reflections on D&T units. The nature of values and the degree of emphasis varied within and across cases. For instance, costs and personal evaluation of materials was a consideration that emerged in the later phases during trials of units. Moreover, values continue to form the basis for a continual interplay not just in rationalising choices of contexts of 'low technology' but also in planning pedagogic actions and activities of assessment within the D&T engagement. This suggests that 'contextual value' plays a significant role as a 'primary generator' (Darke, 1979) in scoping authentic technological design problems.

An iterative reviewing of cognitive, affective, conative (anticipated, situational actions) and behavioural components of values characterised the process of engagement. The paper argues that a conative component comes into play when contextualising or evaluating technologies. For instance, in Case III, thinking about range of useful maps possibilities led to novel expressions of caste maps, DJ maps which address social sensitivities and embody culturally-embodied knowledge structures and at the same time enabled situating the body mapping activity for discussing gendered identity and bodies of differently-abled within the larger context of 'mapping realities' and 'representations'.

Analysis of cases leads to an understanding about values being embodied in experiences, reflection, and context. They often are tacit, emergent and evolve across various phases of technological engagement. Values become explicit in thought and action through a generative discourse of thinking (about needs, contexts, constraints, etc.), materialising (negotiating ideas, resources, actions, etc.), reflecting (introspecting, assessing, evaluating impacts, etc) and often involves metacognition (what led to an outcome, alternatives to tailoring outcomes, effective engagements, etc.). The understanding of the play of values calls for a need to not just use frameworks for assessing and measuring ideas being engaged with or as reductive categories imposing integration within teacher practices. On the contrary, the understanding of values can reliably be used to organise a variety of learning experiences in different DTE units to provide wholesome, meaningful experiences. In addition, the model imagined for teacher learning, which aligns continual professional development along with developing curricular resources, holds potential for challenging narrow perceptions about technology, encouraging sustained synthesis of knowledge, skills and culture, besides contributing to the development of community of practitioners in the field. A continual exploration that builds an understanding of 'values' and 'values-in-contexts' around experiences perceived to be involving *no*, *low* and *high* technology could be critical in relating to practitioners and envisioning curricular discourses that are informed, authentic and contextually relevant.

Acknowledgements

I thank the participants of the DTE course and my institute for providing the academic space and opportunity to conduct such pedagogic experiments. My deep gratitude to Shikha for being an enabler through the study.

References

- Arnold, D. (1946/2000). *Science, Technology, and Medicine in India: The New Cambridge History of India*, Vol III, No. 5. UK: Cambridge University Press.
- Barab, S., & Squire, K. (2004). Design-Based Research: Putting a Stake in the Ground. *The Journal of The Learning Sciences*, 13(1), 1-14.
- Basu, P. (2015). Technoscientific practices and ethics (pp 145-160). In R. Raina (ed.) *Science, Technology and Development in India: Encountering values*. New Delhi: Orient Blackswan Pvt. Ltd.
- Batra, P. (2005). Voice and Agency of Teachers: Missing Link in National Curriculum Framework 2005. *Economic and Political Weekly*, 40, 40, 4347-4356.
- Bhattacharyya, P. K. (2004). *Technology and children*. New Delhi: National Council of Educational Research and Training (NCERT).
- Breckon, A. (1998). National curriculum review in design and technology for the year 2000. *Journal of Design & Technology Education*, 3(2), 101-105.
- Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of The Learning Sciences*, 2(2), 141-178.
- Calder, R. (1968). *The Evolution of the Machine*. New York: American Heritage Publishing Co., Inc.
- Choksi, B., Chunawala, S., & Natarajan, C. (2006). Technology education as a school subject in the Indian context. In K.S. Volk (Ed.), *International conference technology education*

- in the Asia Pacific Region: Conference 2006 proceedings: Articulating technology education in a global community* (pp. 280–290). Hong Kong: Hong Kong Technology Education Association and Hong Kong Polytechnic University.
- Coles, R., & Norman, E. (2005). An exploration of the role values play in design decision-making. *International Journal of Technology and Design Education*, 15(2), 155-171.
- Cross, N. (2006). *Designerly Ways of Knowing*. London: Springer-Verlag.
- De Vries, M. (2018). Technology Education: An International History (pp73-84). In M. J. De Vries (ed.) *Handbook of Technology Education*. The Netherlands: Springer International Publishing.
- Darke, J. (1984). The primary generator and the design process. In N. Cross (Ed.), *Developments in Design Methodology* (pp. 175–188). Chichester: John Wiley & Sons.
- Earl, L. (2003). *Assessment of Learning, for Learning, and as Learning. Assessment as Learning: Using Classroom Assessment to Maximise Student Learning*. Thousand Oaks, CA, Corwin Press.
- Eggleston, J. (1992). *Teaching Design and Technology*. Buckingham: Open University Press.
- Eggleston, J. (1977). *The Sociology of the School Curriculum*. London: Taylor & Francis.
- Gol (1966). *Education & National Development: Report of the Education Commission 1964-66*. New Delhi: Ministry of Education, Government of India.
- Gilbert, J. (2005). *Visualization in Science Education*. The Netherlands: Springer.
- Hammersley, M. (2011). Models of Research: Discovery, Construction, and Understanding (pp 123-137). In M. Hammersley (Ed.) *Methodology: Who Needs It?* London: Sage Publications Ltd.
- 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.
- Holdsworth, I., & Conway, B. (1999). Investigating values in secondary design and technology education. *Journal of Design & Technology Education*, 4(3), 205-214.
- HTSS (1938). *Basic National Education*. Hindustani Talimi Sangh, Sevagram, Wardha and Navajivan Press, Ahmedabad.
- Khunyakari, R. (2015). Experiences of Design-and-Make Interventions with Indian Middle School Students. *Contemporary Education Dialogue*, 12, 2, 139-176.
- Khunyakari, R. (2008). *Investigating middle school students' perceptions of technology and developing design and technology education units to study students' design productions*. Unpublished PhD Thesis. India, Mumbai: Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research
- Kimbell, R., Stables, K., & Green, R. (1996). *Understanding Practice in Design and Technology*. Buckingham: Open University Press.
- Kincheloe, J. (2003). *Teachers as Researchers: Qualitative Inquiry as a Path to Empowerment*. London: RoutledgeFalmer.

- Kumar, K. (2009). *What Is Worth Teaching?* New Delhi: Orient BlackSwan Pvt. Ltd.
- Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. UK: Cambridge University Press.
- Layton, D. (1993). *Technology's challenge to science education: Cathedral, Quarry or Company Store?* Buckingham: Open University Press.
- Halstead, J. M., & Taylor, M. J. (2000) Learning and Teaching about Values: A review of recent research. *Cambridge Journal of Education*, 30(2), 169-202.
- Mayo, C. W., & Crockett, W. H. (1964). Cognitive complexity and primacy-recency effects in impression formation. *The Journal of Abnormal and Social Psychology*, 68(3), 335-338.
- Natarajan, C., & Chunawala, S. (2009). Technology and vocational education in India. In *International Handbook of Research and Development in Technology Education* (pp. 105-116). Brill Sense.
- NCERT (2007). *Position Paper of the National Focus Group on Work and Education*. New Delhi: National Council of Educational Research and Training.
- NCERT (1979). *Socially Useful Productive Work Curriculum*. New Delhi: National Council of Educational Research and Training.
- Pavlova, M. (2005). Knowledge and Values In Technology Education. *International Journal of Technology and Design Education*, 15, 127-147.
- Pavlova, M. (2002). "Teaching" Values in Technology Education: A Critical Approach for the Theoretical Framework (pp 96-102). In H. Middleton and D. Roebuck (eds.) *Learning in Technology Education: Challenges for the 21st Century*. Centre for Technology Education Research, Griffith University.
- Prime, G. (1993). Values in Technology: Approaches to Learning. *Design & Technology Teaching*, 26,1,30-36.
- Rowell, P. M. (2004). Developing technological stance: Children's learning in technology education. *International Journal of Technology and Design Education*, 14(1), 45-59.
- Schwartz, S. H. (1992). Universals in the content and structure of values: Theory and empirical tests in 20 countries. In M. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 25, pp. 1-65). New York: Academic Press. [http://dx.doi.org/10.1016/S0065-2601\(08\)60281-6](http://dx.doi.org/10.1016/S0065-2601(08)60281-6)
- Trimingham, R. (2008). The role of values in design decision-making. *Design and Technology Education: An International Journal*, 13(2), 37-52.
- Vyas, H. K. (2009). *Design the International Movement With Indian Parallel*. India, Ahmedabad: School of Interior Design (SID) Research Cell, CEPT University.

Using CAVTA (Conversation Analysis and Variation Theory Approach) in a Learning Study on Welding

Nina Kilbrink, Stig-Börje Asplund



Nina Kilbrink
Karlstad University
Sweden
nina.kilbrink@kau.se



Stig-Börje Asplund
Karlstad University
Sweden
stig-borje.asplund@kau.se

ABSTRACT

This study is conducted as a collaborative study between two researchers and one vocational teacher in the Industrial Programme at the upper secondary vocational education in Sweden. The study is conducted in iterative cycles and focuses on actual teaching of a technical vocational object of learning (to make a TIG-weld) in school. The research project is funded by the Swedish Institute for Educational Research. The study is based on two theoretical frameworks; the variation theory (Marton & Tsui, 2004) and conversation analysis (Sidnell, & Stivers, 2013). These theories have been used for planning the teaching as well as for analysing data from the iterative cycles. Combining these two frameworks is a fairly new approach, but it has previously been done in a few studies (cf. Asplund & Kilbrink, 2018). However, there are no previous action research studies that we know about where these theories are combined in the planning of and teaching a specific object of learning. We use the abbreviation CAVTA (Conversation Analysis and Variation Theory Approach) for the combination of these theories as a tool in practice-based school research. Inspired by the learning study method, this study is conducted in three iterative cycles. However, this study is based on CAVTA as the theoretical framework, in contrast to previous learning studies. Data consists of video recorded lessons and audio recorded conversations between the researchers and the teacher to follow the process of working with this collaborative method in relation to a technical vocational object of learning. The results from this study show how the teaching content in relation to the object of learning is made visible in the interaction. Furthermore, the critical aspects are displayed more explicitly in teaching over time, based on analysing, planning and evaluating teaching with a starting point in CAVTA.

Keywords: CAVTA, Conversation Analysis, Variation Theory, Learning Study, Technical Vocational Education

Introduction

In today's education arena there are claims on teaching on a scientific basis and for teachers to develop professionally in their classroom teaching (cf. Carlgren, 2017; Marton, Cheung and Chan, 2019; Pang and Ling, 2012). Carlgren (2009) argues for conducting more studies in natural occurring classroom situations and Lo (2012) states that teaching theories need to be tested in practice and that it is important to test and develop the use of variation theory by developing "more learning studies that target objects of learning outside of the cognitive domain" (Lo, 2012 p 198), which could relate to both technical and vocational learning which often is referred to as a more "practical" learning (cf Kilbrink, 2018, p 195). In a vocational classroom teaching is often conducted in interaction between teacher and students, as well as in interaction with tools, artefacts and learning content (cf Asplund & Kilbrink, 2018).

In relation to technical objects of learning and vocational education, there is a lack of research on teaching on a scientific basis as well as studies on teachers' professional learning (cf Asplund & Kilbrink, submitted; Kilbrink & Asplund, 2018, June). One way of teaching on a scientific basis and develop professionally is to participate in a learning study. Learning study is a method for developing teaching in relation to a specific content, based on the variation theory of learning (cf. Ling & Marton, 2012; Pang & Ling, 2012). In order to develop the learning study method and variation theory, more studies in more areas and in relation to more theories are needed. In previous studies, we have used CA and variation theory to analyse actual teaching on welding (Asplund & Kilbrink, 2018; Kilbrink & Asplund, 2018) and found this to be a productive method in our pursue to understand learning processes in technical vocational education. As a result of this, we decided to use those theories as integrated (CAVTA) in a collaborative learning study project.

Context of the study

This study is conducted as a collaborative study between two researchers and one vocational welding teacher in the Industrial Programme at the upper secondary vocational education in Sweden. The study is conducted in iterative cycles and focuses on actual teaching of a technical vocational object of learning (OoL) (to make a TIG-weld) in school. There are three new students participating in the teaching activities in every cycle, and for the students it is the first time that they are introduced to the TIG-welding method at school (but not the first time they are welding). The research project is funded by the Swedish Institute for Educational Research (ref no 2017-00056).

Theoretical background and method

The present study is based on two theoretical frameworks; the variation theory (Lo, 2012; Marton & Tsui, 2004) and conversation analysis (CA) (Sidnell, & Stivers, 2013), where variation theory can highlight *what* is learned and CA can help us understand the aspect of *how* something is learned (Asplund & Kilbrink, 2018). These theories have been used for planning the teaching as well as for analysing data from the iterative cycles. Combining these two frameworks is a fairly new approach, but it has previously been done in a few studies (cf. Asplund & Kilbrink, 2018; Emanuelsson & Sahlström, 2008; Kilbrink & Asplund, 2018). The combination can contribute to an understanding of the whole learning process, concerning both content and form issues. However, there are no previous action research studies that we know about where these theories are combined in the planning of and teaching a specific OoL. We use the abbreviation *CAVTA* (*Conversation Analysis and Variation Theory Approach*) for the combination of these theories as a tool in practice-based school research. Inspired by the learning study method (cf. Kilbrink et al., 2014; Lo, 2009; Marton & Ling, 2007; Pang & Ling, 2012), this study was conducted in three iterative cycles. However, this study is based on CAVTA as the theoretical framework, in contrast to previous learning studies, which are primarily based on variation theory solely (cf Kilbrink et. al., 2014; Pang & Ling, 2012).

Data consists of three video recorded lessons (a total of 270 minutes) and 9 audio recorded conversations (a total of 490 minutes) between the researchers and the teacher to follow the

process of working with this collaborative method in relation to a technical vocational OoL (to make a TIG-weld). The video-recorded lessons have been analysed in collaboration between the two researchers and the vocational teacher based on CAVTA, with the overall focus on what content was possible to learn in the interaction between teacher and students. Between the cycles, these analyses influenced how the following cycles were planned and conducted, following the iterative steps of a learning study (Pang & Ling, 2012).

In this article, we direct our focus of the analyses of the interaction on the *critical aspects* (aspects of the OoL that are important to learn), the *critical features* (specific values of the critical aspects) and the *patterns of variation* that were used to highlight the *object of learning* (OoL) (cf Asplund & Kilbrink, submitted; Lo, 2012; Marton & Tsui, 2004) and on how a common understanding was established in the interaction between the teacher and the students (cf Sahlström, 2011).

Analysis and results

The results from this study show how the teaching content in relation to the OoL is made visible in the interaction. Furthermore, the critical aspects are displayed more explicitly in teaching during the process over time, based on planning, analysing, and evaluating teaching with a starting point in CAVTA.

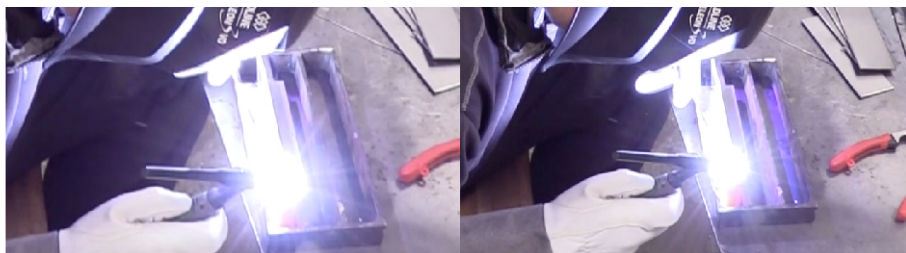
In the first cycle there were a lot of critical aspects, concerning aspects from seeing the melt and handling the tools, to ergonomics and cleaning; and the critical aspects were different among the students, depending on what critical aspects emerged in the interaction between teacher and student there and then (Kilbrink & Asplund, 2018, June).

In the second cycle, three critical aspects (*the melt*, *the length of the movement with the additive material* and *the length of the arc*) were put into focus. Based on CAVTA it was decided in the planning between the teacher and the researchers to endeavour to let the student show their understanding of those critical aspects in interaction and to use patterns of variation (mainly contrasting) for finding the critical features of the critical aspects (see Example 1 below).

In the third cycle, the three critical aspects from the second cycle were kept, but the structure of the lesson was changed, so that the students were able to show their understanding of the critical aspects early in the lesson. Thereby, the teacher could decide if and when to add further critical aspects (which in this case were chosen to be *ergonomics* and *where to put the additive material*, based on the analysis of the previous cycles). The students were encouraged to verbalise their knowledge regarding the critical aspects, as well as displaying the critical features in their actual welding in interaction with the teacher. When the different critical aspects are focused on in the interaction, they are temporarily foregrounded as subordinated OoL with their own critical aspects (cf Asplund & Kilbrink, submitted).

Below we show an example of how working with establishing a shared understanding regarding a critical aspect and the use of contrast as pattern of variation can be used in the teaching situation.

- 1 T: får ja se om du förstod detta jag sa med e: jag ser
can I see if you understood what I said with e: I see
2 att (.) de-det du gör nu är det korta rörelser eller är det
that (.) wh-what you do now is that short movements or is it
3 långa rörelser me:d tillsatsmaterialet?
long movements wi:th the additive material?
4 S: långa va?
long right?
5 T: nej jag tyckte du gjorde rätt kort jag (.) ta :e: gö:
no I thought you made quite short I thought (.) take: e: do:
6 överdriv så får jag se hur du gör om det blir långa
exaggerate so I can see how you do if it gets long
7 rörelser
movements
8 S: (5.0)/((för vänster hand fram och tillbaka))#
(5.0)/((moves left hand back and forth))#



- 9 S: dä:r är långa
ther:e are long
10 T: preci:s å då går du över å gör korta istället då
exa:ctly and then you go over and do short ones instead then
11 S: (6.0)/((gör mindre rörelser än i rad 8 med vänster hand))#
(6.0)/((makes smaller movements then in line 8 with left hand))#



- 12 T: det är bra du har förstätt vad de: vad jag menar med det
that's good you have understood what i:t what I mean with that

Example 1 Establishing shared understanding of long and short movements

In the *Example 1* above, we can see how the teacher actively works on establishing a shared understanding of what they are orienting towards regarding the critical aspect *length of the movements* when the student is TIG-welding. In the first three lines, the teacher's talk and the content made relevant show that it is longitudinally linked to a prior, shared teaching situation ("can I see if you understood what I said", line 1), and the teacher also positions the student epistemically as someone who should be a candidate accountable for understanding how to do short and long movements with the additive material as critical features of the OoL to put a TIG-weld. Epistemic topicalisation is the way participants in interaction claim and display their knowledge and understanding, and according to Sahlström (2011) epistemic topicalisations seem to be quite common in teaching situations (see also Melander & Sahlström, 2010). In line 4 then, the student positions himself epistemically, and claims that

what he is doing is long movements. By adding “right?” at the end of the turn, he seeks the teacher’s confirmation, which he does not receive, however, since the teacher says that he “thought” that the student “made quite short” movements (line 5). Here, the teacher displays a cognitive state (“I thought”) and initiates a correction, but opens up for the student to correct himself by encouraging him to “exaggerate” so that he can see what it looks like when he makes long movements (lines 5-7). As a response to this, the student moves his left hand in which he holds the additive material, back and forth with long movements (line 8) and then he says “ther:e are long”, thus once again claiming knowledge of how to do long movements (line 9). This time, the teacher agrees and direct after that, he requests the student to do short movements instead (line 10), which he also does in line 11. In line 12 then, the teacher confirms and praises the student’s action, saying “that’s good” and also confirms that the student has “understood” what he meant “with that”.

The example shows how the teacher and the student, together and socially, orient towards a common understanding regarding the critical features of how to do long and short movements with the additive material. By encouraging the student to do short and long movements, the teacher works with *contrast* as pattern of variation regarding the length of the movements, and through these actions, epistemic stance is topicalised several times in the example (cf. Heritage, 2013; Sidnell, 2012). When a knowledge asymmetry is displayed in the interaction, the teacher actively works with re-establishing a knowledge symmetry (lines 6-7) in order to change the epistemic possibilities for the student. The topicalisation of epistemic stance, the oriented-to-knowledge asymmetries, and the re-establishment of a knowledge symmetry that is oriented to by the teacher, are concrete elements that together constitute learning situations (Sahlström, 2011). Thus, the excerpt above does not only illustrate what happens when the teacher works with establishing a shared understanding of how to make long and short movements with the additive material when TIG-welding, but also how these activities could be described as situations in which the student’s are doing learning (cf. Asplund & Kilbrink, 2018).

Discussion

As we have shown in previous studies, the combination of CA and VT into CAVTA provides a basis for an analysis of learning processes focusing on both the how and the what aspects of learning; that is, we can reach a deeper understanding of the learning process in relation to a specific learning content (cf Asplund & Kilbrink, 2018; Kilbrink & Asplund, 2018). However, in this study we also show how CAVTA can be a tool also in planning and conducting teaching.

The analysis in Example 1 above shows how CAVTA creates conditions for learning a specific content and how it establishes a common understanding in the interaction. Previous studies state that the use of patterns of variation improves “student learning outcomes” (Lo, 2012, p 83). Using contrast of the critical features long and short movements in the interaction between teacher and student in the example above thereby both improves the student’s possibilities to discern the critical features, but also the teachers’ possibility to interpret whether he/she and the student has established a shared understanding of the learning content.

In light of this, CAVTA can be used in natural occurring teaching situations with a specific focus on establishing a common understanding in the interaction between teacher and student of which specific aspects of OoL should be oriented to and highlighted. Thus, CAVTA can contribute to creating fruitful conditions for the students to learn what they are intended to learn.

Previously, the vocational teacher who participated in this study mostly worked with showing only the right value of the critical aspect. Thereby, it was left to the students themselves to find the critical features of the OoL. By working systematically in helping the students to discern the critical features by also showing what is wrong (eg contrasting short and long movements), using contrast in the interaction, the right values of the critical aspect *the length of the movement with the additive material* is made visible to the students (see Figure 1).



Figure 18 The right values – the specific critical feature of the critical aspect

One big difference between the first and the following cycles was the amount of critical aspects of TIG-welding in the lesson. When handling the large amount of aspects of TIG-welding in the first lesson, there was not much room for using patterns of variation or to use different semiotic resources simultaneously to establish a shared understanding between teacher and students. When working more systematically in reflecting on what the students were supposed to learn and to focus on fewer, more articulated critical aspects, there was also room for a deeper handling of the learning content in the teaching, to actually reach a shared understanding and to use variation to foreground the critical aspects and the critical features of the OoL.

Conclusions

The conclusions concern both specific and general contributions. The specific contributions concern aspects of teaching and learning to make a TIG-weld. For example, it concerns how CAVTA can be helpful in how the critical features of the OoL to make a TIG-weld can be oriented to and made explicit in the interaction, by combining different semiotic resources and patterns of variation. Also, the use of CAVTA helps illustrate how teaching can be arranged to shed light on students' understanding and learning as well as prior knowledge of TIG-welding in the interaction. Furthermore, it can contribute to a deeper understanding of professional learning on TIG-welding.

There are also general contributions from this study. The general contributions concern for example knowledge of working with a collaborative approach between teachers and researchers in relation to specific OoL in teaching based on CAVTA and how critical features of an OoL can be highlighted in the interaction, by combining different semiotic resources and patterns of variation. Furthermore, we argue that this way of working with analysing data from actual teaching situations can help us find concepts and words for what teachers and students do in the actual learning interaction of the OoL and to possibly display tacit knowledge (cf Asplund & Kilbrink, submitted) and in the long run both contribute to teachers' professional learning and to improving teaching and learning.

References

- Asplund, S-B., & Kilbrink, N. (submitted) Lessons from the welding booth: Theories in practice in an action-oriented Learning study.
- Asplund, S-B., & Kilbrink, N. (2018). Learning how (and how not) to Weld: Vocational Learning in Technical Vocational Education. *Scandinavian Journal of Educational Research* 62(1) 1-16.
- Carlgren, I. (2009). CA-Studies of Learning—From an Educational Perspective. *Scandinavian Journal of Educational Research*, 53(2), 203–209
- Carlgren, I. (red.) (2017). *Undervisningsutvecklande forskning: exemplet learning study*. (Första upplagan, första tryckningen). Malmö: Gleerups

- 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.
- Heritage, J. (2013). Epistemics in conversation. In J. Sidnell, T. Stivers (Eds.), *The Handbook of Conversation Analysis*, Blackwell, London, pp. 370-394.
- Kilbrink N. (2018). Technical vocational education: From dualistic to pluralistic thinking. In: M. de Vries (Ed.), *Handbook of technology education* (pp. 193–204). Springer International Handbooks of Education. Springer, Cham. https://doi.org/10.1007/978-3-319-44687-5_22.
- Kilbrink, N. & Asplund, S-B. (2018). “This angle that we talked about”: learning how to weld in interaction. *International Journal of Technology and Design Education*. (doi: 10.1007/s10798-018-9490-z)
- Kilbrink, N., & Asplund, S-B. (2018, June). Learning to weld in technical vocational education: the first cycle of an action-oriented study. Presented at *PATT36 International Conference: Research and Practice in Technology Education: Perspectives on Human Capacity and Development*, 18th-21th June 2018. Athlone, Ireland.
- Kilbrink, N., Bjurulf, V., Blomberg, I., Heidkamp, A., Hollsten, A-C. (2014). Learning a specific content in technology education: Learning Study as collaborative method in Swedish preschool class using hands-on material. *International Journal of Technology & Design Education*, 4(3) 241–259
- Ling, L. M., & Marton, F. (2012). Towards a science of the art of teaching: Using variation theory as a guiding principle of pedagogical design. *International Journal for Lesson and Learning Studies*, 1(1), 7–22.
- Lo, M. (2009). The development of the learning study approach in classroom research in Hong Kong. *Educational Research Journal*, 24(1), 165–184.
- Lo, M. L. (2012). *Variation theory and the improvement of teaching and learning*. Göteborg: Acta universitatis Gothoburgensis.
- Marton, F., & Ling, L. M. (2007). Learning from “the learning study”. *Tidskrift för lärarutbildning och forskning*, 14(1), s 31–34.
- Marton, F. & Tsui, A. B. (Eds.) (2004). *Classroom Discourse and the Space of Learning*, Lawrence Erlbaum, Mahwah, N.J.
- Marton, F., Cheung, W. M., & Chan, S. (2019). The object of learning in action research and learning study, *Educational Action Research*, DOI: [10.1080/09650792.2018.1489873](https://doi.org/10.1080/09650792.2018.1489873)
- Melander, H., & Sahlström, F. (2010). *Lärande i interaktion*. Stockholm: Liber.
- Pang, M. F., & Ling, L. M. (2012). Learning study: Helping teachers to use theory, develop professionalism and produce new knowledge to be shared. *Instructional Science*, 40(3), 589–606.
- Sahlström, F. (2011). Learning as social action. I J. K. Hall, J. Hellermann & S. P. Doehler (Red.), *L2 interactional competence and development* (ss. 45-65). Bristol: Multilingual Matters.
- Sidnell, J. (2012). “Who knows best?": Evidentiality and epistemic asymmetry in conversation. *Pragmatics and Society*, 3(2), 294-320.

Sidnell, J. & T. Stivers (Eds.) (2013). *The Handbook of Conversation Analysis*. Oxford, U.K.: Wiley-Blackwell.

Formative Assessment in Primary Design Education – involving pupils in clarifying the learning goal of divergent thinking.

Remke Klapwijk, Niels van den Burg



Remke Klapwijk
Delft University of Technology
The Netherlands
r.m.klapwijk@tudelft.nl



Niels van den Burg
Delft University of Technology
The Netherlands
N.A.vandenBurg@tudelft.nl

ABSTRACT

Design and Technology Education is an excellent vehicle for the development of the so called 21st century skills such as creativity, critical thinking and cooperation. However, the development of these skills through design projects does not yet reach its full potential. This is because the learning goals related to these 21st century skills are often not shared with the students. Subsequently self-monitoring and (peer) feedback that move learners forward is frequently absent or superficial.

In this article we describe a case-study in which the teacher shared the goal of divergent thinking with her class of 11 and 12 year olds using an interactive approach. Small drawings were made collectively to visualize the skill. Half-way during the brainstorm session, the pupils were asked to reflect on their divergent thinking skills. These two formative assessment interventions were meant to improve their understanding of the success criteria for divergent thinking and to enable learners to monitor and improve their divergent thinking strategies. The interviewed students developed insight in success criteria related to divergent thinking and could tell about the process and products of divergent thinking in their own words. They were also able to apply these insights to discover strengths and weaknesses in their brainstorm approach and create conditions that would help them to think divergently. The case-study thus emphasizes the value of the well-known key-strategies for formative evaluation (William 2011) in a designerly context. Sharing 21st century learning goals, collecting evidence of learning as well as providing feedback that moves the learning forward needs more attention in both research and educational practices to achieve design and technology education's full potential.

Keywords: Sharing learning goals, formative assessment, divergent thinking, primary education, brainstorming, design and technology education, creativity.

1 Introduction

Robinson (2001) characterises creativity as being at the heart of what it is to be human. And with the growing need for creativity in many occupations, it is more important than ever that students learn to develop original solutions in Design and Technology Education (DTE). For students, these outcomes do not have to be new in the sense that they have never been thought of before, but they should learn to create solutions that are new for them (Cropley and Urban 2000). This type of creativity is called “little c” creativity and contrasted with “big” creativity (Kaufman and Beghetto, 2009). Craft (2001 in Cremin *et al* 2012, p.77) defines it as “*purposive imaginative activity generating outcomes that are original and valuable in relation to the learner*”.

D&T projects are an excellent vehicle to develop creativity (Klapwijk 2017; Benson 2017). However, the full potential is not achieved. This has many reasons, Atkinson (2000) for example points towards the inflexible use of the design cycle in classrooms. Our starting point here is that learners participating in authentic design and technology projects are confronted with the need to apply a great variety of 21st century skills. These skills are generally characterized as being transversal and are associated with higher order skills and behaviours that represent the ability to cope with complex problems and unpredictable situations (Voogt and Pareja Roblin 2012). However, the learners may not have a clear idea about the skills they are meant to learn.

To change this, creativity and other higher order learning goals in design education need to be explicitly shared, clarified and understood. To achieve this, the Delft University of Technology and various partners developed a series of tools for formative evaluation of 21st century skills called “Make Design Learning Visible” (Klapwijk e.a. 2019; Klapwijk e.a. 2017). Two features are central in the approach.

- Tools were developed to make the five strategies of formative evaluation proposed by Wiliam (2011; 2018) feasible in the context of authentic D&T projects, see figure 1.
- Design skills related to the 21st century skills were defined, see figure 2.

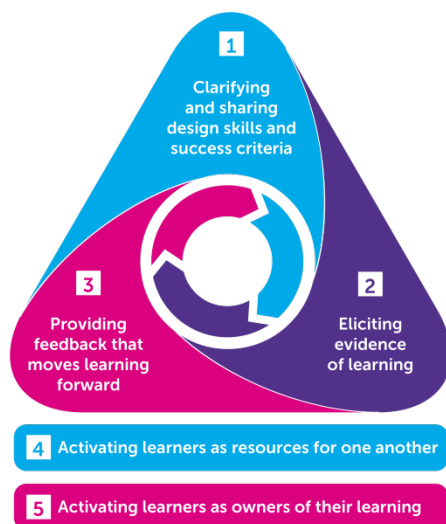


Figure 1. Five key-strategies for formative assessment in DTE (Klapwijk e.a. 2019; based on Wiliam 2011).



Figure 2. Hexagon model of design skills (Klapwijk e.a. 2019; Klapwijk 2018).

The DTE literature has extensively emphasized the opportunities within design projects to master 21st century skills (PATT 2016), however knowledge on ways to share these skills is still scarce. Therefore, a case-study was conducted on Wiliam's first strategy: clarifying, sharing and understanding design skills. The central research question is: *What are possible insights learners develop when the learning goal divergent thinking is shared in an interactive and visual way. How does this guide their mastering of divergent thinking?*

The outline of this paper is as follows. In section 2, the value of formative assessment of creativity is grounded in the literature. Section 3 focuses on sharing learning goals in D&T education. The intervention and the research methodology are described in section 4. Results and conclusions are presented in sections 5 and 6.

2 Formative assessment of creativity and higher order skills

Assessment of creativity is even for experts often a perilous undertaking. Creativity involves the development of something new and relevant (Mumford, 2003). In the recent International Handbook of Technology Education, Klapwijk (2018) argues that objective measurement of creativity is impossible as standards to judge the value of novelty cannot be set in advance. In a society, dialogue and exchange of insights are crucial for the recognition of creativity. Schools also need to develop learning communities that recognize novelty through discourse. Formative assessment (FA) of creativity is therefore a sensible approach.

FA is meant to directly influence the learning process:

“the process of seeking and interpreting evidence for use by learners and their teachers to decide where the learners are in their learning, where they need to go and how best to get there” (Broadfoot et al., 2002 pp. 2-3).

A key strategy in FA is active involvement of learners so they can learn from their mistakes (Hattie & Timperley 2007). They should learn to evaluate their own creative skills and design results and be able to discuss the work of their peer-students. Stables e.a. (2016), FA expert

in DTE argues that dialogue lies at the centre of the learning process, including private inner processes of “talking to ones-self”.

The direct connection of FA with the teaching-learning process and the increased self-direction of students as they actively pursue learning goals has a profound effect on learning outcomes. When using FA effectively, the rate of student learning increases up to 50 to 70 percent (William, 2006; William 2018). This is verified for many learning domains, Black and William (1998, pp 61) conclude that “*Despite the existence of some marginal and even negative results, the range of conditions and contexts under which studies have shown that gains can be achieved must indicate that the principles that underlie achievement of substantial improvements in learning are robust*”.

However, is FA also possible for higher order skills? In a comparative study on inquiry based learning in the field of physics by White and Frederiksen (1998), formative evaluation of research skills such as critical thinking was applied. Each research skill was clarified through a discussion and followed by self-monitoring activities and peer-feedback. A comparison with a control group, showed that the learners applying FA developed their research skills at a much faster rate and obtained better results on physics content tests.

Butler (1988) applied FA on divergent thinking. She discovered that feedback in the form of comments containing a compliment and a suggestion, e.g. “you thought of quite a few interesting ideas, maybe it is possible to think of more unusual ideas other children may not think of” had a profound effect on the next brainstorm. Grades or grades in combination with the same comments had no effect.

Both studies indicate that understanding how success look likes has a profound effect on the acquisition of higher order skills.

3 Sharing learning goals in D&T education

How should teachers share higher order learning goals in DTE? First of all goals should be formulated in a context-free way (Clarke 2005; William 2018). Often learning intentions are shared in a contextual way, for example, students are told that they need to be able to analyse a questionnaire about movie-going habits. However, the real learning intention is that students are not only able to analyse a questionnaire on movie-going habits, but can analyse questionnaires on any topic. Second, although the skills need to be context-free, they should be shared as specific as possible to make self-monitoring possible.

Based on these insights, Klapwijk e.a. (2017; 2019) described seven key design skills in a context-free way, see figure 2. None of these skills are tied to a specific stage in the design project, each skill is important all over the design project.

Creativity is quite a catch-as-catch-can concept and at least two thinking processes are involved: divergent and convergent thinking (Howard-Jones 2002). Creativity is furthermore related to the ability to take risks. The hexagon model divides creativity therefore into:

- thinking in all directions (divergent thinking),
- making ideas tangible (converging thinking),
- and making productive mistakes.

The seven design skills are relevant in DTE ranging from elementary to university education.

4 Methodology

A case-study was conducted in which a teacher of 11-12 year olds shared the goal of divergent thinking in an interactive and visual way prior to a brainstorm. Students suggestions on how to think in divergently were collected and the class collectively devised symbols to depict the suggestions. Half way during the brainstorm a whole class moment of reflection took place to evaluate the divergent thinking process so far, followed by a second brainstorm round (figure 3).

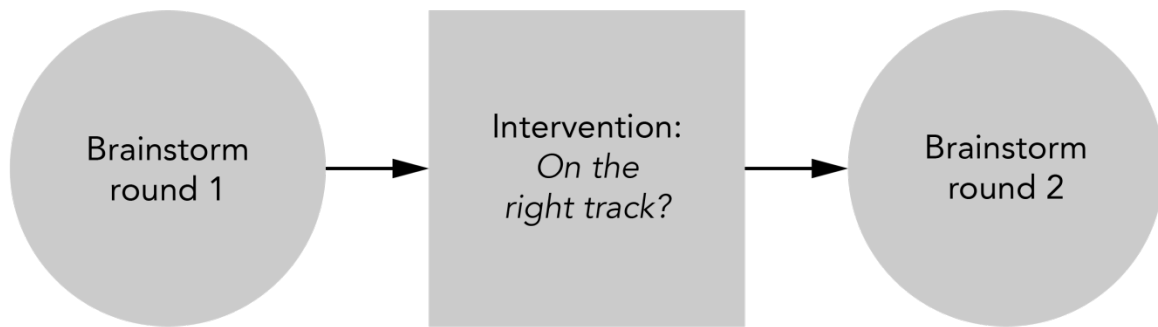


Figure 3. Brainstorm with FE intervention

The case study took place at a primary school in the Netherlands. Although the pupils were accustomed to team collaboration on a range of real life projects, divergent thinking was relatively new as these projects did not focus on “creating something new”.

The pupils were asked to design new activities for the gym of the future in a design approach based on the Creative Problem Solving model in which divergent and convergent activities alternate, see Schut e.a. (2017). In six sessions (1,5 hour) teams explored the design problem and developed solutions (figure 4). The teams were put together by the teacher at the start of the design project.

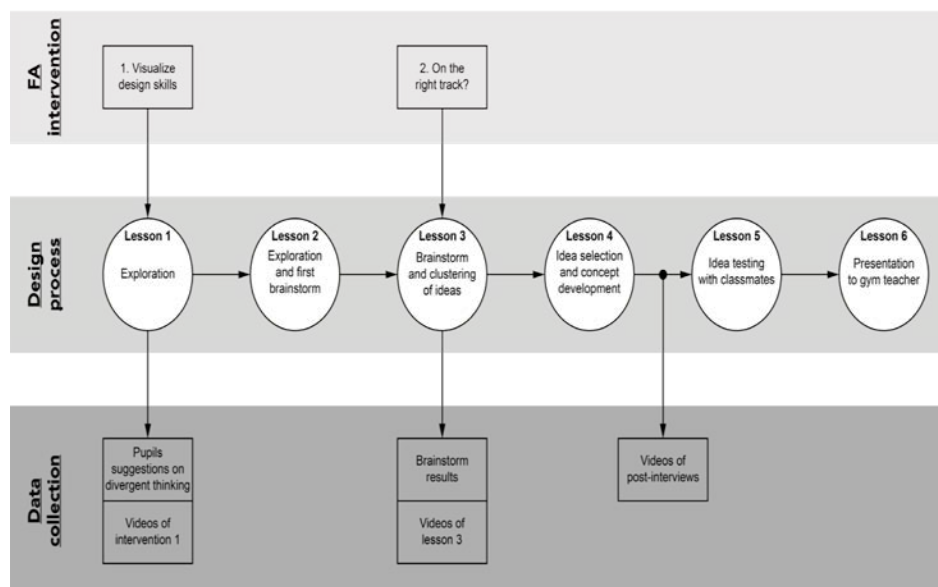


Figure 4. FA Intervention, Design process and Data collection.

The FA intervention consisted of two parts. The tool “Visualize Design Skills” was used to share and clarify the learning goal of divergent thinking in 11 minutes. In the third session, an individual brainstorming session was conducted inspired by “words and pictures” that were randomly pulled out of an envelope. Here, the tool “On the Right Track?” was applied. The brainstorm was paused after ten minutes. The class reflected on the quality of their divergent thinking before continuing the brainstorm for another ten minutes.

Video-recordings were made during whole class formative evaluation activities and transcribed. Two teams that were thought representative by the teacher were specifically followed and their brainstorm recorded. Pair-wise post-interviews with these pupils were conducted focusing on the pupils awareness of divergent thinking and their ability to assess their brainstorm process and outcomes. In addition, specific moments taken from the videos were shown to obtain an explanation about what is happening. Students work was collected: the visualized learning goals (figure 5) and brainstorm results.

5 Results

In this section the two interventions are described and how the learners understood the goals and processes of divergent thinking and applied it to their own thinking processes in the first and second round.

Intervention: Visualize divergent thinking

On a smartboard, an empty matrix is shown and teacher Katy tells her class that they will generate design ideas for the gym of the future next week.

She then asks: “*What do we need to do when we think in different directions?*” It is quiet for a moment, then a Anna, proposes: “*To agree with each other*”. The teacher reacts and asks her class: “*When everyone has to agree, is this a way to think in different directions?*” While making eye-contact with Anna, Katy says “*I don’t think so, but you helped us a lot because due to your suggestion, other pupils have raised their hands*”.

Next, classmate Evelyn suggests that you need more people to think in different directions and other pupils agree with her. When Katy asks “*How can we show that in a little drawing?*” a classmate proposes to draw a number of persons (suggestion 1).





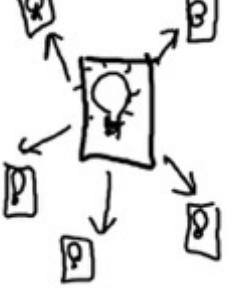


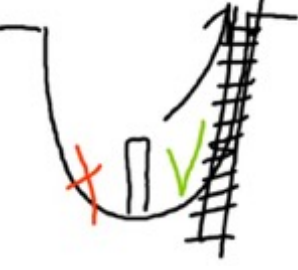
 <p>1. You need a team, everybody thinks in a different direction</p>	 <p>2. Collect many ideas.</p>	 <p>3. Do not hold on to your own idea</p>	 <p>4. Combine ideas</p>
 <p>5. Use an idea to develop a new idea</p>	 <p>6. Talk together about ideas</p>	 <p>7. Think about the opposite</p>	 <p>8. Persevere, do not stay trapped in your "learning" pit</p>

Figure 5. Suggestions on divergent thinking

Eight suggestions are generated. The teacher keeps on asking questions about what is exactly meant by the contributors and engages the whole class in developing pictograms. She invites them to suggest drawings, draws out loud, paraphrases and uses class suggestions on the fly. Idea's for most drawings come from pupils that were not the first contributor. When Nick suggests that one should not hold on to one's own idea, Isa proposes to put a red cross.

Miranda finds it difficult to explain her idea. After her classmates visualize her idea, Miranda reacts happy – almost surprised - that her idea has been visualized so well.

Both product-related advices (many ideas, variety, new combinations) as process-advices (such as combine ideas, think of the opposite and do not hold on to your own idea) are developed. The concept of quality developed is closely related to insights in the scientific creativity literature and rather similar to Guilford's operationalization. The teacher acts as a gate-keeper by making clear that some suggestions do not belong to divergent thinking.

Intervention On the right track?

After ten minutes, the brainstorm is paused and the class reflects on the quality of their divergent thinking in a teacher led discussion. Katy starts with questions about the amount of ideas, the variety and if there were new ideas. The class responds with a big yes when she asks if the pupils were able to think of many of ideas.

When the class discusses if their ideas are varied Miranda tells "*I succeeded because I first thought of a tag game, after that I came up with a ball game and then another ball game*". She explains that she succeeded because the pictures drawn from the envelope helped her. Sophia recognizes this and refers to suggestion 4 "*When you had a picture and did not know what to do, you could look at other pictures and I combined these*".

When discussing their ability to think of new ideas, Mary tells that her first ideas were similar to the ones in a previous brainstorm (in session 2), but developed new ones once she started using the pictures from the envelope. Jean then tells that he was fixated by the ideas from the previous brainstorm and approximately half of the class indicates that they had the same problem. Some teams discover that their ideas were not related to their design question.

Next, the teacher shows the visualized suggestions from lesson 1 and points out what went well, e.g. combine ideas. The class thinks of what to do in the next brainstorm round: focus on the goal (design question), do not stick to your idea, draw and write and persevere. After this, ideation continues.

Post-interviews

The interviews give self-descriptions of how the learners understood the learning goal of divergent thinking and applied it in the brainstorm.

The pupils have captured the idea that one needs to think of many and varied ideas. When explaining "think in different directions" they give the interviewer examples such as "first you have an idea with a ball game and next an idea about dancing".

They also understand that divergent thinking is about having new ideas. Most pupils use the term new in the sense of an idea that they or their class did not have the idea before. Two pupils mention generating unusual ideas: "*It should be something that is totally different. For example a piano lowered in the floor, sponges a person can tumble on or a very strange dance battle with a flashlight in the gym.*"

The pupils have developed their own words to describe divergent thinking. Quite often, the interviewees use expressions from the collective drawings like you should not stick to one idea or use a cooking pan to mix ideas. Lianne: "*You and me, for example Jean and Livia, all the best ideas are put in a pan*". Livia: "*You should think of the opposite*". They also develop their own expressions, the video's show e.g. Lara telling Lianne to "empty your head" when Lianne complains about being stuck to an idea.

The pupils were able to judge the quality of their own brainstorm outcomes by looking at how fluent and varied they have been thinking. Often they described that the first three minutes – when they were not yet allowed to use the pictures of the envelope - were not fruitful in developing new and varied ideas, and how they got inspiration from the pictures.

In the interviews they tell about moments that they did not get new ideas or only very similar ideas. They used the suggestions from "Visualize Design Skill" and things said during the break to continue to think divergently, like "*this time (after the break) I was able to persevere instead of thinking I am not able to do this*".

When asked to compare the brainstorm before and after the break, pupils judge that the thought more divergently after the break.

- Jean realizes for the first time during the break – after the comment from Mary- that he was fixated on ideas from a previous brainstorm.
- Danique realizes that she got sometimes stuck looking to a picture from the envelope and not understanding what it meant. After the break, she could let go and was better able to relax and if needed she picked new pictures: “I worried less in this round”.
- Denise and Sophie think that they had less ideas in the second round but the quality is better as they are more related to the design question and unusual.

Only Livia judges that her brainstorm results were better in the first round: “My ideas were dried out because I had used all the pictures”.

Conclusions:

The approach used to clarify learning intentions clearly helped the pupils to understand what divergent thinking is and how to think in a divergent way. They had a clear picture of the intended outcome: many and varied ideas.

The strength of the first intervention is the fact that pupils put the goal in their own words and pictures, remember and apply it well. They often use words that were coined by their peers, created their own terms and were able to give many examples to explain divergent thinking.

Both interventions helped them to monitor their thinking behaviour and to redirect it. Although the interactive visualization had already a positive effect, the combination with the break in the brainstorm process helped them even more to recognize their ability to think in a divergent way. They understood how the used brainstorm method (pictures and words) helped them to develop ideas.

When pupils generate success criteria for a skill, some elements may be underrepresented, e.g. the fact that divergent thinking aims at unusual ideas was not clear for most pupils. However, this does not have to be a problem as long as teachers notice this and plan other interventions to clarify these unknown aspects.

According to their own perception, the majority of the pupils was better able to think in a varied way during the second round. They redirected their thinking as a result of their own monitoring and changed small elements in their thinking approach, but sometimes they only know that it is not going well.

The case study indicates that the pupils are able to improve their divergent thinking due to FA. However, additional research comparing the progress of classes using FA with control groups is needed. Furthermore we could not include our comparison of the outcomes of the two rounds, that did not show clearly that outcomes in round two were substantially better. In both rounds, unusual and varied ideas were found.

As the learners developed their own terminology to explain what went well and not well in their divergent thinking and actively evaluated their brainstorm, we assume that it is beneficial to share higher order learning goals in a visual and interactive way and to use a break to check if their thinking is on the right way. Through this they develop a sense of quality, an important condition for learning (Sadler 1989).

Acknowledgments

This publication is part of the research project “Co-Design with Kids” in which scientific partners (Delft University of Technology, The Hague University of Applied Sciences and Inholland University of Applied Sciences) together with partners from education and industry developed “Your Turn” a toolbox for co-design sessions at primary schools. The project is funded by The Netherlands Organisation for Scientific Research (NWO), The Netherlands Initiative for Educational Research (NRO), Expert Organization of Science and Technology South Holland (EWTZH) and several other partners. The formative evaluation approach in the case-study was developed by the Delft University of Technology in cooperation with other partners in the project “ Make Design Learning Visible” (Ontwerpen in Beeld) funded by the The National Platform Science & Technology (PBT), the Netherlands. The English version was developed in cooperation with the Goldsmith University. We thank the involved teachers, students and partners for their cooperation.

References

- Atkinson, S. (2000) ‘Does the Need for High Levels of Performance Curtail the Development of Creativity in Design and Technology Project Work?’ *International Journal of Technology and Design Education*. 10 (3), 255-281.
- Benson, C. (2017). Setting the context: design and technology and creativity, In C. Benson and S. Lawson, *Teaching Design and Technology Creatively* (pp. 51-72). Routledge.
- Black, P., & William, D. (1998). Assessment and classroom learning. *Assessment in Education: principles, policy & practice*, 5(1), 7-74.
- Butler, R. (1988) ‘Enhancing and undermining intrinsic motivation: The effects of task-involving and ego-involving evaluation on interest and performance’. *British Journal of Educational Psychology*. 58 (1), 1-14.
- Clarke. S. (2005), *Formative assessment in the secondary classroom*, London; Hodder and Stoughton.
- Craft, A. (2001) ‘Little c creativity’, in Craft, A., Jeffrey, B. and Liebling, M. (eds) *Creativity in Education*. London: Continuum.
- Cremin, T., A. Craft and J. Clack (2012) *Creative Little Scientists: Enabling Creativity Through Science and Mathematics in Preschool and First Years of Primary Education*, D2.2. Conceptual Framework, Addendum 2 of 4; *Literature Review of Creativity in Education*, www.creative-little-scientists.eu (accessed 14 July 2016).
- Cropley, A. J., & Urban, K. K. (2000). Programs and strategies for nurturing creativity. In K. . Heller, F. J. Monks, R. F. Subotnik, & R. J. Sternberg (Eds.), *International handbook of giftedness and talent* (pp. 481–494). Oxford: Elsevier.
- Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational Research*, 77(1), 81-112.
- Howard-Jones, P. (2002) ‘A dual-state model of creative cognition for supporting strategies that foster creativity in the classroom’. *International Journal of Technology and Design Education*. 12 (3), 215-226.

Kaufman, J. C. & Beghetto, R.A. (2009) "Beyond Big and Little: The Four C Model of Creativity". *Review of General Psychology*, 13(1): 1–12.

Mumford, M. D. (2003). Where have we been, where are we going? Taking stock in creativity research. *Creativity Research Journal*, 15, 107–120.

Kimbell, R., & Stables, K. (2007). Further Performance Assessment. *Researching Design Learning: Issues and Findings from Two Decades of Research and Development*, Springer Science & Business Media 99-138.

Klapwijk, R. , E. Kok, J. Visschedijk and E. Holla 2017. *Ontwerpen in Beeld, Ontwerpend Leren, Formatief Evalueren*, Delft University of Technology & Design Agency Meeple.

Klapwijk, R. (2017). Creativity in Design. In C. Benson and S. Lawson, *Teaching Design and Technology Creatively* (pp. 51-72). Routledge.

Klapwijk, R. M. (2018). Formative assessment of creativity. In: De Vries, M. J. (Ed.). *Handbook of technology education*. Springer International Publishing, pp. 765-783.

Klapwijk R.M., E. M. Holla and K. Stables, 2019. *Make Design Learning Visible: Formative assessment tools for design thinking*, TU Delft and Goldsmith University.

PATT-32, 2016. *Technology Education for 21st Century Skills*, Utrecht, The Netherlands, August 23-26, 2016 (pp. 463-472). University of Applied Sciences.

Robinson, K. (2001) *Out of Our Minds: Learning to be Creative*. Chichester: Capstone.

Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instructional science*, 18(2), 119-144.

Schut, A., van Doorn, F., Klapwijk, R., & Buchner, D. (2017). Creativity in children's design processes: identifying indicators of design fixation. In *DS 88: Proceedings of the 19th International Conference on Engineering and Product Design Education (E&PDE17), Building Community: Design Education for a Sustainable Future, Oslo, Norway, 7 & 8 September 2017* (pp. 436-441).

Stables, K, R. Kimbell, T. Wheeler & K. Derrick (2016). Lighting the blue touch paper: Design talk that provokes learners to think more deeply and broadly about their project work, *PATT Conference*.

Voogt, J. and Pareja Roblin, N., (2012) A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies, *Journal of Curriculum Studies*, 32(2), 721-741.

White, B. Y., & Frederiksen, J. R. (1998) Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and instruction*, 16(1), 3-118.

William, D. (2011). *Embedded Formative Assessment*, Bloomington: Solution Tree Press.

William, D. (2018). *Embedded Formative Assessment*, Bloomington: Solution Tree Press (revised edition).

The body within the loop - identifying the metaphor ecology of educational resources in computer programming.

Andreas Larsson



Andreas Larsson
Linköping University
Sweden
andreas.b.larsson@liu.se

ABSTRACT

Programming languages – both textual and visual – are based on linguistic relations between language and syntax. Learning computer programming is highly dependent on the ability to interpret metaphoric expressions such as “the strings can be enclosed in”, “the function returns a value” or “the program will wait until you click on the icon”. As a consequence, knowledge about metaphors used in computer programming educational resources is central to uncovering the way we think about code. Primary metaphor theory hypothesizes that metaphoric language is based on linguistic units termed primary metaphors grounded in sensorimotor experiences. The aim of this study is to identify how computer programming is presented in four formal and informal coding resources available and applicable to teachers and pupils in Sweden. The resources were analysed using qualitative metaphor analysis reveal how sensorimotor experiences contribute to the way we interpret and communicate metaphoric expressions common in computer programming. The analysis of the resources revealed several metaphoric expressions such as “within the body of the loop”, “... the most important building block” where the primary metaphors ESSENTIAL IS INTERNAL and ORGANISATION IS PHYSICAL STRUCTURE is mapped abstract aspects of computer programming. Furthermore, the study shows discrepancies in what types of primary metaphors that is used among the different resources, indicating that the different resources provide learners with different opportunities to conceptualise computer programming. Indicative to the respective resources is that texts targeted to children and beginners utilise metaphors related to human actions and movement while resources directed to more advanced users provide a wider variety of metaphoric mappings. In summary, this study shows that, by describing the metaphoric ecology of an educational resource it is possible to predict how programming metaphors are being interpreted, thus aiding learners to form the primary metaphors needed to conceptualise computer programming in an efficient way.

Keywords: Conceptual metaphors, Programming, Technology education

Introduction

Ever since the introduction of the personal computer, interface designers have had to rely on the use of metaphors and analogies in order to communicate the abstract functions of the “mysterious” machine (e.g. the word processor is like a *typewriter* or that one is able to “*place* documents in the *trash*”). Early metaphor research within the computer science domain mainly concerned human-machine behaviour (e.g. Carroll & Mack, 1985). However, due to the increasing importance of computer education, there is a growing body of metaphor related research in the realm of computer science education (e.g. Blackwell, 2006; Hui & Umar, 2011; Manches, McKenn, Rajendran, & Robertson, 2019)

Programming languages – both textual and visual – are packed with metaphoric relations between natural language, functions and syntax. The programmer “places *files* in *folders*”, “catches information” and “builds entire structures of data”, while the program “reads text”, “recognises faces” or “the program *tells* the user when the buss will arrive” (cf. Colburn & Shute, 2008). Metaphors like these, grounded in our everyday experiences, serve as a basis for describing the abstract aspects of programming that also appear in the code. In that sense it is reasonable to claim that metaphoric reasoning and thinking play an influential role in both teaching and learning computer programming.

Lakoff and Johnson (1980) introduce the term conceptual metaphor as a main component in how we communicate about the abstract in terms of the concrete. Their main claim is that conceptual metaphors are the foundation of human cognition and that conceptual metaphors arise from recurring everyday experiences (Johnson, 2007; Lakoff & Johnson, 1980, 1999). As a result, we are able to discuss economy in terms of verticality (e.g. “the central bank just *lowered* the interest rate”) or to speak about arguments in terms of war (e.g. his rhetoric was a bit *defensive* so he *lost* the debate”), where qualities of the tangible (up/down and defensive/offensive) are mapped in to the intangible (interest rates and rhetoric) part of the metaphor. Grady (1997) refers to these mappings as primary metaphors. He states that primary metaphors are experientially motivated in the sense that they arise from particular sensorimotor experiences and that they serve as building-blocks in “the semantic and conceptual machinery” (p. 264). Furthermore, he claims that primary metaphor analysis might play an important role in addressing how particular metaphors and concepts can arise from sensorimotor experiences.

Over the last decade, scholars have begun to recognise the importance of metaphoric language as a foundation for thinking and reasoning in different areas of STEM education (e.g. Jeppsson, Haglund, & Amin, 2015; Niebert, Marsch, & Treagust, 2012; Woollard, 2005). Emanating from metaphor theory developed, by amongst others, Lakoff and Johnson (1980, 1999) and Grady (1997), these studies serve as examples of how embodied metaphors are manifested in both textbooks, classroom dialogue and gestures. The results of the studies indicate that there are identifiable patterns in how metaphors are used to conceptualise different phenomena. As such, they also show that metaphor analysis is a fruitful way to uncover the structure of metaphoric reasoning, thinking and communication.

Metaphoric language is seldom uniform. However, Gibbs (2006) claims that metaphoric language appears to stem from patterns of “imaginative” re-enactment of the actions referred to in a specific metaphoric expression (e.g. interpreting the expression “to *catch* information” by unconsciously recruiting bodily experiences of catching an object). As such, both Grady (1997) and Gibbs (2006) highlight the importance of everyday experiences for both producing and interpreting metaphoric language. Although neither Grady (1997) nor Gibbs (2006) claim that metaphoric language is interpreted in the same way by everyone in every situation, they do state that one, by attending to the experiential motivation of the primary metaphors can predict, with a high degree of accuracy how individuals will conceptualise and interpret abstract phenomena.

Aim and research questions

The aim of this study is to identify how computer programming is presented in four different coding resources available and applicable to teachers and pupils in Sweden (i.e. formal educational literature, programming books for children, and open access coding resources). In response to the aim, the following research questions will be raised

- i. What typical metaphoric expressions are used in the four educational resources to describe programming concepts?
- ii. How do the identified metaphoric expressions relate to primary metaphors?
- iii. How do the four educational resources vary in terms of which metaphoric expressions are being used to communicate programming concepts?

Method

The present study is based on a qualitative metaphor analysis of four different coding resources available and applicable to teachers and pupils in Sweden. With the ambitions to uncover “the nature between linguistic texts and the interpreter’s full understanding of the texts in its context” (Fillmore, 1985, p. 231), the texts were analysed to identify and categorise metaphoric mappings present in the resources (cf. Grady, 1997). In relation to the broad aim of this study, resources were chosen to reflect the diversity in the ways that computer programming is communicated.

The respective resources aim to address rather distinct audiences; hence the resources differ both in linguistic properties, image content, number of code examples, etc. The following section will serve as a short presentation of the resources selected for the study.

- The children’s book, Woodcock (2017), is targeted at children (approximately age 8-12) with no previous programming experiences. The book is based around Python, with an aim to guide children in coding their first computer game. Short code examples are accompanied by simple explanatory texts, often framed in colourful boxes and figures. However, some of the texts are on a more advanced level, implying that there is a need for support from a more advanced user.
- The teacher’ book, Skansholm (2018), is targeted towards in-practice teachers and aims to provide a wide coverage of programming terms and concepts. The book is structured in a step-by-step manner, and presupposes none, or little previous programming experience. The pages are filled with dense sections of explanatory texts and JavaScript-code examples. Apart from explaining the code, the author serves the reader with definitions of common computing concepts.
- The on-line resource kodcentrum.se is developed by a non-profit organisation aiming to promote programming and computational thinking in both schools and other arenas. This particular on-line resource is targeted towards teachers who want to explore how to implement programming at a beginner’s level in the classroom. The on-line course is structured in sections where short instructional texts are combined with code examples in Scratch (a visual programming environment).
- Python is the full documentation concerning the programming language Python. It is accessible on-line and provides the reader with extensive code examples and explanations to all functions available in Python. The resource is structured according to functions, meaning that the user has to know what to look for in order to use the resource properly. In this sense it presupposes an experienced programmer, however not necessarily experienced in Python.

The analysis was performed as follows. Firstly, metaphoric mappings in the data corpus were identified and notated (e.g. “the program will *read* data”, “*inside* the *body* of the loop”). Secondly, the identified metaphoric mappings were categorised in relation to the primary metaphors and experiential motivations deduced by Grady (1997) (e.g. INANIMATE PHENOMENA ARE HUMAN AGENTS, ESSENTIAL IS INTERNAL). The metaphoric mappings were identified in their respective original language (three in Swedish and one in English). The categorisation of the metaphoric mappings was later performed using the English translations.

Results

The result of the analysis reveals salient differences in how primary metaphors are used to communicate computer programming within the different recourses. This section presents an overview of the metaphoric expressions identified in the data corpus in relation to their respective experiential motivation. The section is structured as follows. Firstly, the distribution of the identified metaphoric mappings will be presented, both in relation to the respective educational resources and experiential motivations. Secondly, metaphor analysis of typical examples of metaphoric mappings will be presented per educational resource. The results will later be discussed as a whole in the coming sections.

The distribution of identified metaphoric mappings

Table 1 shows the distribution of metaphoric mappings per resource, and primary metaphors. The number of mappings is notated in increments of five mappings per (+). The number of metaphoric mappings identified in the respective resources varies from 18 (kodcentrum.se) to 39 (Teacher’s book). There are also apparent differences in which and how many different kinds of primary metaphors are utilised within the respective resource. The resources with a higher number of different primary metaphors generally display a more even distribution (Table 1).

Table 1: The distribution of the identified metaphoric mappings per educational resource and primary metaphor

0-5 = + 6-10 = ++ 11-15 =+++ 16-20 =++++ 21-25=+++++	EVENTS ARE ACTIONS, INANIMATE PHENOMENA ARE HUMAN AGENTS	ESSENTIAL IS INTERNAL	AN EVENT IS MOTION OF AN OBJECT	CATEGORIES/SETS ARE BOUNDED SPATIAL AREAS	STRUCTURE IS PHYSICAL STRUCTURE
Children’s book	+++++	++			
Teacher’s book	++	++++	+	++	+
Kodcentrum.se	++	+	+		
Python	+++	++	+	++	++

Metaphoric language in relation to experiential motivation

The metaphor analysis of the children’s programming book reveals metaphoric expressions grounded in mainly two types of primary metaphors: EVENTS ARE ACTIONS, INANIMATE PHENOMENA ARE HUMAN AGENTS and ESSENTIAL IS INTERNAL (Table 1). The experiential motivation of the respective primary metaphors suggests that the metaphoric language of this resource stems from sensorimotor experiences of correlating the presence of human agents in relation to their environments (e.g. “the computer *asks* the user” or “the loop will *write*”) and the correlation between the inside of an object and its inner properties (e.g. “A loop-body can

contain another loop-body” or “insert more elsif-statements”). In most cases, the target-domains for the metaphoric expressions are either computer or program (Table 2).

The book targeted at in-service teachers utilise a number of different primary metaphors, with an emphasis towards the ESSENTIAL IS INTERNAL and the CATEGORIES/SETS ARE BOUNDED SPATIAL AREAS primary metaphors (Table 1). The experiential motivation of the respective primary metaphors suggests that the metaphoric language of this resource stems from sensorimotor experiences of the correlation between the inside of an object and its inner properties (e.g. “there are a lot of variables *in* a program” or “an attribute *contains*”) and the tendency for similar objects to be clustered together (e.g. “they are surrounded by brackets” or “placing a value *in* a variable”. Generally, the target domain of bounded-space-metaphors are various types of objects (e.g. variables described in terms of boxes) and by combining these with internal-metaphors it is possible to conceptualise e.g. “placing a value *in* a variable” based on a combination of primary metaphors stated above.

Table 2: Examples of typical metaphoric expressions identified in the respective educational resource

	EVENTS ARE ACTIONS, INANIMATE PHENOMENA ARE HUMAN AGENTS	ESSENTIAL IS INTERNAL	AN EVENT IS MOTION OF AN OBJECT	CATEGORIES/SETS ARE BOUNDED SPATIAL AREAS	(LOGICAL STRUCTURE IS PHYSICAL STRUCTURE
Children’s book	The computer asks the user This program asks The loop will write	One loop-body can contain another loop-body Insert more else-if statements			
Teacher’s book	So, the program asked for input-data and you wrote it The first line will read	A lot of variables in a program An attribute contains Within the brackets you can give information to the method	When you return To place a value in a variable	Place a value in a variable This object contains information They are surrounded by characters	The most important building blocks Place an element
Kodcentrum.se	The robot [graphic representation] does everything we tell her Or else the program will not understand Get different scripts to run	The number in the move-script	How do we get the robot [graphic representation] to do as we want We can follow every step she takes by reading the code		
Python	Print () function produces The while-loop executes Is recognized by the interpreter	The built-in variable The list might contain Within the basic block	Returned by the loop Arguments are passed	The [string] can be enclosed between square brackets Within a basic block	The built in loop Python supports slicing Grouping statements

The online-resource centres around movement, thus the utilisation of the primary metaphor AN EVENT IS MOTION OF AN OBJECT. The experiential motivations for the respective primary metaphors show that a large portion of the metaphoric language is grounded in experiences of the correlation between perceiving motion and being aware of a change in the world-state around us. In most cases, the metaphoric expressions are related to what is observable by

the programmer, in this case the graphic representations of code that is drag-and-dropped onto a control-window in the software. In this way, both the code-blocks and the explanatory texts become metaphors for the events that are running inside the computer. Movement is also central to many of the metaphoric expressions relating to the primary metaphor INANIMATE PHENOMENA ARE HUMAN AGENTS. This is manifested in expressions such as “this script *tells* the robot to move”.

The documentation for Python utilises various primary metaphors, both in natural language, but also in the related code examples. A lot of the expressions are grounded by the human-agent-metaphor with e.g. loops or functions as their target domains. As such, the Python documentation is another example where human action are used as a way to conceptualise computational concepts. Another important aspect of the metaphoric expressions found in the Python documentation is the use of the (LOGICAL) STRUCTURE IS PHYSICAL STRUCTURE. The utilisation of this primary metaphor suggests that a big part of the metaphoric language is grounded in experiences of observing the part-whole structure of objects while forming cognitive representation of the logical relationships within them. This allows for communicating computer programming in terms of e.g. structuring, moving objects, using different tools.

Discussion

The analysis of the four educational resources has revealed a large number of different metaphoric expressions used to describe different computing concepts. However, by attending to the variance in metaphor use among the resources, it becomes apparent that different target groups are provided with different possibilities in how to conceptualise programming concepts. Since interpreting metaphoric language involves re-enacting previous sensorimotor experiences, a smaller number of metaphors provided in an educational resource reduces the opportunities for learners to utilise previous sensorimotor experiences to reason about the abstract aspects of programming (c.f. Gibbs, 2006). Also, there is a risk that learners are unable to interpret the metaphor at all.

When attending to the experiential motivations for the respective primary metaphors, it is obvious that it is possible to combine two or more primary metaphors into more complex, conceptual metaphors. One example would be the connection between the (LOGICAL) STRUCTURE IS PHYSICAL STRUCTURE metaphor and the CATEGORIES/SETS ARE BOUNDED SPATIAL AREAS METAPHOR. When combining these primary metaphors into conceptual metaphor, it is possible to conceptualise programming as a way of organising objects instead of writing lines of code, and by adding the INANIMATE PHENOMENA ARE HUMAN AGENTS it is also possible to utilise words such as “print”, “catch” and “get” into the syntax in a natural way. In that sense it is reasonable to state that the smaller number of primary metaphors provides fewer possibilities for learners to form novel conceptual metaphor for programming concepts based on their own sensorimotor experiences (c.f. Grady, 2005; Lakoff & Johnson, 1999).

When interpreting the different primary metaphors in relation to the respective educational resources, the following patterns can be recognised:

- The resources targeted towards younger children and/or beginners utilise fewer number of primary metaphors and tend to emphasize EVENTS ARE ACTIONS and INANIMATE PHENOMENA ARE HUMAN AGENTS metaphors. Resources presupposing a more advanced user tend to utilise a higher number of primary metaphors distributed in a more evenly way (Table 1).
- The target domains of the metaphors identified in the resources directed towards younger children and/or beginners are mainly connected to the artefact itself e.g. the computer or the robot, while resources presupposing a more advanced user tend to use metaphors in relation to the functions and/or the structure of the code.

- Based on the varying types of metaphors used in the different resources, it is reasonable to suggest that teachers and students conceptualise computing concepts grounded in different sensorimotor experiences based on which resource they have been using at the moment.

Conclusions and implications

In summary, this study has revealed how primary metaphors serve as mappings between abstract concepts and concrete experiences in the different computer programming resources. The results show that metaphors are used in various ways depending on the presupposed target-group of a specific educational resource.

By highlighting the differences and similarities in the use of metaphoric language, this study has been able to describe what I choose to call a *metaphor ecology* within the four resources. The metaphor ecology is based on the following tenets

- typical metaphoric expressions
- the primary metaphoric content of said metaphors in relation to their corresponding sensorimotor experiences
- the possibilities for learners to form novel metaphors.

By describing the above stated aspects of a *metaphor ecology*, it is possible to accurately predict the sensorimotor ground that learners need to utilise in order to interpret the metaphoric language (cf. Gibbs, 2006), how they might combine primary metaphors into more complex and flexible conceptual metaphors (cf. Lakoff & Johnson, 1999) and also to help them form the primary metaphors needed to conceptualise computer programming in a fruitful and efficient way (cf. Grady, 1997; Grady & Johnson, 1997).

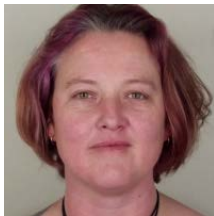
References

- Blackwell, A. F. (2006). Metaphors we program by: Space, action and society in Java. *Proceedings of PPIG*, 7-21.
- Carroll, J. M., & Mack, R. L. (1985). Metaphor, computing systems, and active learning. *International journal of man-machine studies*, 22(1), 39-57.
- Colburn, T. R., & Shute, G. M. (2008). Metaphor in computer science. *Journal of applied logic*, 6(4), 526-533.
- Fillmore, C. J. (1985). Frames and the semantics of understanding. *Quaderni di semantica*, 6(2), 222-254.
- Gibbs, R. W. (2006). Metaphor Interpretation as Embodied Simulation, 434.
- Grady, J. (1997). *Foundations of Meaning: Primary Metaphors and Primary Scenes*: eScholarship, University of California.
- Grady, J. (2005). Primary metaphors as inputs to conceptual integration. *Journal of Pragmatics*, 37(10), 1595-1614. doi:10.1016/j.pragma.2004.03.012
- Grady, J., & Johnson, C. (1997). Converging Evidence for the Notions of subscene and primary scene.

- Hui, T. H., & Umar, I. N. (2011). Does a Combination of Metaphor and Pairing Activity Help Programming Performance of Students with Different Self-Regulated Learning Level? *Turkish Online Journal of Educational Technology*, 10(4), 121-129.
- Jeppsson, F., Haglund, J., & Amin, T. G. (2015). Varying Use of Conceptual Metaphors across Levels of Expertise in Thermodynamics. *International Journal of Science Education*, 37(5-6), 780-805. doi:10.1080/09500693.2015.1025247
- Johnson, M. (2007). *The meaning of the body: Aesthetics of human understanding*. Chicago, IL: University of Chicago Press.
- Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago : Univ. of Chicago Press, 1980.
- Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh : the embodied mind and its challenge to Western thought*. New York : Basic Books, 1999.
- Manches, A., McKenn, P. E., Rajendran, G., & Robertson, J. (2019). Identifying Embodied Metaphors for Computing Education. *Computers in Human Behaviour*.
- Niebert, K., Marsch, S., & Treagust, D. F. (2012). Understanding needs embodiment: A theory-guided reanalysis of the role of metaphors and analogies in understanding science. *Science Education*, 96(5), 849-877. doi:10.1002/sce.21026
- Skansholm, J. (2018). *Programmera på riktigt : för lärare på högstadiet* (Upplaga 1 ed.): Mondial.
- Woodcock, J. (2017). *Programmeringsprojekt för barn*: Tukan förlag.
- Woollard, J. (2005). The implications of the pedagogic metaphor for teacher education in computing. *Technology, Pedagogy Education*, 14(2), 189-204.

A methodological approach to the study of indigenous curriculum design for Hangarau, Māori technological practice in Aotearoa-New Zealand.

Ruth Lemon, Kerry Lee, Hemi Dale



Ruth Lemon
University of Auckland
New Zealand
ruth.lemon@auckland.ac.nz



Kerry Lee
University of Auckland
New Zealand
k.lee@auckland.ac.nz



Hēmi Dale
University of Auckland
New Zealand
hemi.dale@auckland.ac.nz

•ABSTRACT

Hangarau or Māori-medium Technology is a distinct curricular approach to teaching technology in Aotearoa-New Zealand classrooms. In Hangarau, Māori values, beliefs and language are the foundation of all teaching and learning. Hangarau provides a space for children to engage with purposeful problem-solving to meet needs in meaningful contexts. An ethical approach is encouraged, where students consider the environment, society and the problem, with a focus on ensuring that any proposed solutions have zero impact on the environment. This is part of the reason that ancestral practices are central. Students conduct research into materials and processes their ancestors used as part of re-framing and re-claiming traditions, bringing them into the contemporary world. Although the New Zealand English-medium technology curriculum has been well researched, minimal research has involved the Hangarau curriculum. As a consequence, there is not an established or recognised research methodology for qualitative study focusing on New Zealand's indigenous technology curricula. This paper outlines research which investigated the key components of a research methodology for the qualitative study of an indigenous technology curricula. Thematic analysis was utilised via key documents which were sourced via the Official Information Act (1982), and data gathered using a combination of expert interviews and document analysis. This paper outlines seven principles for an ethical approach to Māori research and a model which was developed to introduce the key findings indicating relationality and prominence of the historical, political, economic and socio-cultural influences.

•**Keywords:** indigenous curriculum, Māori, New Zealand, technology, curriculum development, Hangarau

Introduction

Researchers have written about the value of past knowledge (De Vries, 2006; Jones, 2003; Lee, 2011; Williams, 2018). De Vries (2006), in his argument for the 'retrospective' texts exploring the histories of the Technology curriculum, states, "you can learn from the past how to act in the future" (p.3). We argue that the narratives of the Hangarau or Māori-medium Technology curriculum document are a valuable tool in developing pedagogical and content knowledge for effective classroom implementation of Hangarau. The idea of the past informing the future is integral to kaupapa Māori research (research from a Māori paradigm), connecting to the idea of ngā taonga tuku iho (ancestral treasures passed down through generations). The past connects the present to the future. The inclusion of mātauranga Māori (Māori knowledge-bases) must be normalised both in research and throughout the education sector. This paper introduces the research context, outlines the theoretical background and key work that informed the study, followed by a discussion of the methodological approach.

Research context

Māori-medium education resulted from the realisation in the 1970s that the number of proficient Māori language speakers had declined dramatically, which led to the language revitalisation movement of the 1980s in Aotearoa-New Zealand. In a Māori-medium immersion context, 50-100 percent of classroom instruction is delivered in the Māori language. The first Māori language curriculum documents were written in 1996 after the New Zealand Curriculum Framework had been translated (Ministry of Education [MoE], 1993a, 1993b). Since 2008, the New Zealand Māori-medium national curriculum *Te Marautanga o Aotearoa* (MoE, 2008) has guided the planning and delivery of educational experiences for children in Māori-medium immersion contexts. This study focused on levels 1-4 of the curriculum and children aged between five and 12, attending primary and intermediate school in Aotearoa-New Zealand.

Like the the New Zealand English-medium Technology curriculum, the Hangarau curriculum (MoE, 2008) provides a space for children to engage in purposeful problem-solving to meet an identified need. Foundational to all teaching and learning are Māori values, beliefs and language. The curriculum document is structured using two key whenu (strands): Ngā Āhuatanga o Te Hangarau (The Nature of Hangarau); and Te Whakaharatau Hangarau (Hangarau Practice, incorporating knowledge and skills). There are five aho (contexts) to which Hangarau classroom practice may belong. They are:

- *Te Tuku Mōhiohio*: the communication of information.
- *Hangarau Kai*: systems, processes, and materials in growing, harvesting, storing, and cooking food.
- *Hangarau Koiora*: conservatory and medicinal practices and ethical debates.
- *Ngā Hanga me Ngā Pūhanga Manawa*: structures, from the simple to the complex.
- *Te Tāhiko me te Hangarau Whakatina*: electronics and control technology.

The first iteration of the Hangarau curriculum was developed between 1996 and 1999. The second iteration of the Hangarau curriculum was developed between 2006 and 2008, and gazetted as a compulsory part of the national curriculum from February 2011 (MoE, 2009, p.3812).

Theoretical background

Three key pieces of research informed this paper. Stewart (2007) utilised a situated form of critical discourse analysis as one of the methods to critically explore the contents of the Pūtaiao (Māori-medium science) curriculum. Critical discourse analysis is an extension of Habermas' earlier work focusing on the subjective nature of communication in the production of knowledge. Stewart's research explored dialectical tensions between the concepts of 'Māori science' and 'science *in* Māori', arguing the need to conduct this research from a Kaupapa Māori paradigm.

McKinley (1995) conducted seminal 'insider' research from a postmodernist, feminist Māori perspective, examining the processes involved in writing the Pūtaiao (Māori-medium Science)

curriculum. She identified a ‘Māori’ construct in the curriculum using Foucault’s notions of discourse. Foucauldian ideas of power supported an examination of the dominant discourses while the Pūtaiao curriculum was being drafted. Dale’s (2016) narrative of the development of the Tikanga-ā-iwi (Māori-medium Social Sciences) curriculum is also from the perspective of an expert ‘insider’, in his critical analysis of the socio-cultural, political and historical aspects that contributed to the shaping of the Tikanga-ā-iwi curriculum document.

McKinley (1995) and Dale’s (2016) studies are valuable to this research because they posit that, although the curricula were being written at different times and influenced by different political and socio-cultural factors, there were parallels in the steps experts took while developing their curriculum statements, which had methodological implications.

Methodology

In order to investigate the historical, political, economic and socio-cultural influences which impacted on the development of New Zealand’s unique indigenous Hangarau (Technology) curriculum, an appropriate research methodology needed to be developed, and be informed by wider curriculum research. This section outlines the methodology and the wider study to situate the need for the development of the research methods which forms the basis of this paper.

The larger study focussed on the Hangarau curriculum document, between 1995-2008. During this time-frame two complete curriculum documents were developed, providing a wealth of data and functioning as a focus for the overarching research question and sub-questions, as represented in Figure 1. The addition of the Hangarau Matihiko (Māori-medium Digital Technologies) area in 2017 equated to a partial change to the Hangarau curriculum, so it lay beyond the scope of this research.

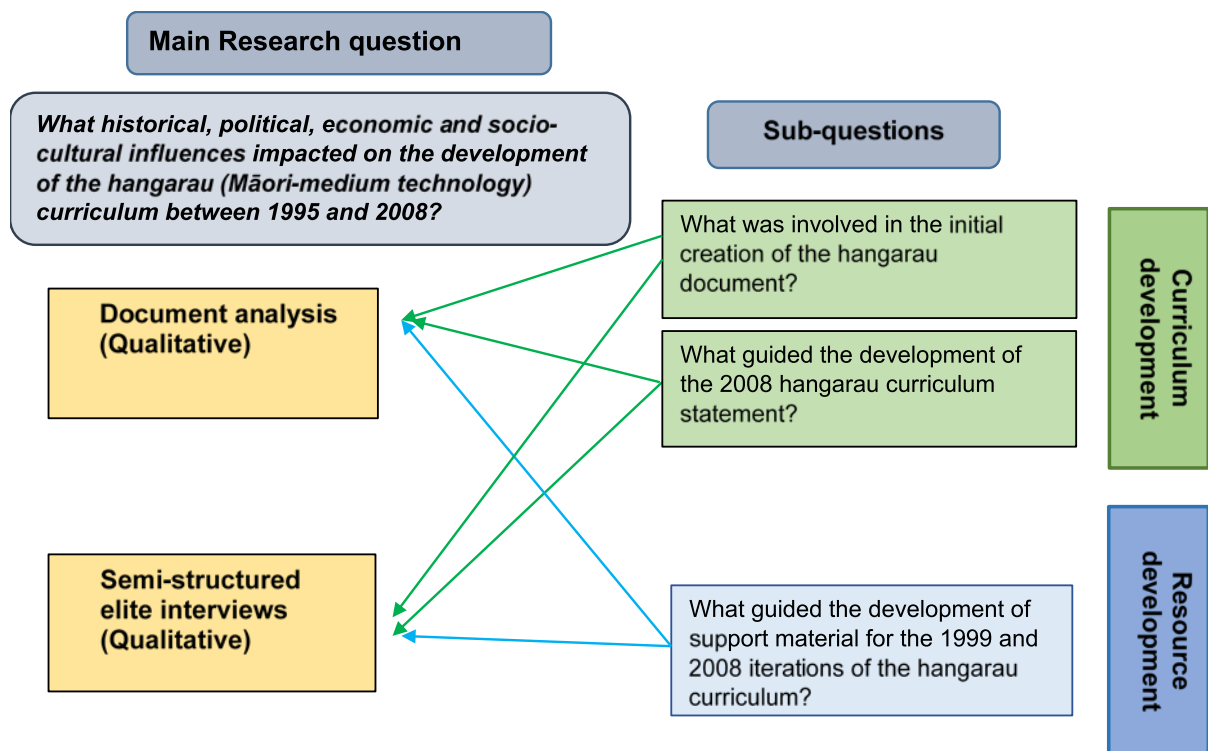


Figure 1 The selected methods utilised to investigate the overarching research questions

The following outlines the methodological decisions with regards to the larger study before findings are discussed in relation to this paper’s research question: What are the key

components of a relevant research methodology for the qualitative study of an indigenous technology curricula?

Document analysis and semi-structured narrative interviews with expert-participants were identified as the most appropriate methods. They facilitated access to the data and allowed for effective examination of the research questions (McCulloch, 2004; Kvale & Brinkmann, 2015).

Document analysis involves studying documents to provide evidence supporting the reconstruction of specific historical events, developing and extending the researcher's understanding of those events (Danto, 2008; McCulloch, 2004). Documents available in the public domain became one of the first sources of information because McKinley (1995) and Dale (2016) had identified 'parallel' development processes with the English-medium curriculum. Documents available via the MoE official and parliamentary information advisors were accessed through a series of requests under the Official Information Act (1982).

Semi-structured interviews allow for flexibility in participants' personal accounts (Kvale & Brinkmann, 2015). Hour-long interviews were held with experts involved in writing the Hangarau document. Each interview was recorded and transcribed in full. Four initial themes were identified through reading narratives about the processes of curriculum design (McKinley, 1995; Dale, 2016):

- How the expert-participant became involved in curriculum development; roles they played; people they worked with; their aims for the document.
- Consultation and design with regards to a corpus of Māori knowledge and its relationships to Hangarau.
- The evolution of the language; linguistic demands and needs envisioned for teachers and learners.
- External bodies of knowledge and their relationships to Hangarau.

The available data came from a very small sector, so purposive sampling was used. Compton (2001) is a seminal researcher in the field. Her PhD research focussed on the reflections of key participants involved in the development of the English-medium Technology document, making this research a potential model. Compton (2001) utilised asynchronous data collection with emailed and face-to-face interviews. The nine participants in her study were colleagues, grouped according to their community of practice. However this current research did not need this differentiation as the expert-participants had been involved in curriculum design, implementation and development of curriculum support materials.

Figure 2 outlines the sample selection process followed with tuakana (expert-participants). Two participants responded prior to the follow-up phone call and consented to a semi-structured interview. The two participants were key people involved in the development of Hangarau, whose combined expertise spanned both iterations of the Hangarau curriculum and the development of supporting resources.

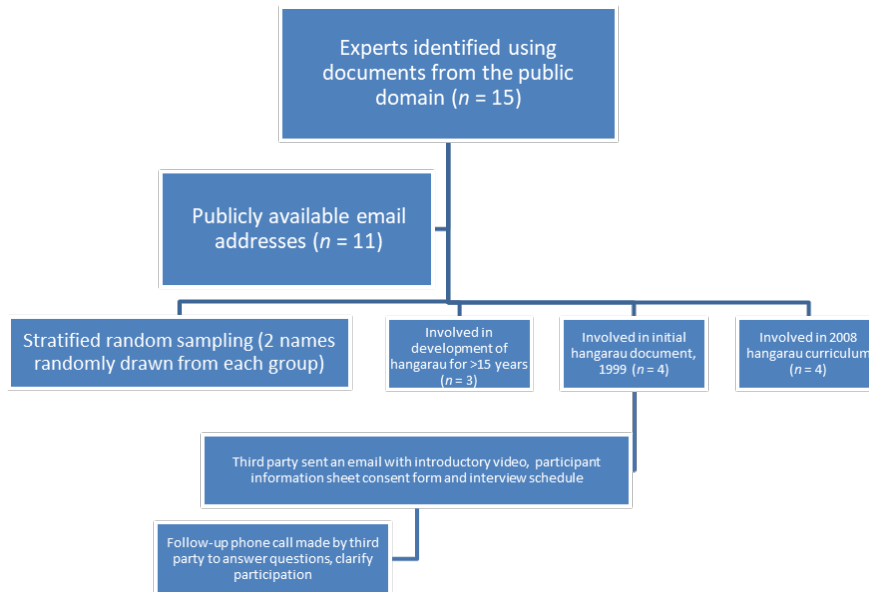


Figure 2 Sample selection process followed with tuakana (expert-participants)

Timeline

The initial timeline utilised a linear sequence of data collection and analysis as represented in Figure 3. The first phase of document analysis informed the second phase, semi-structured interviews which informed the third, the analysis of data.



Figure 3 Initial phases for data collection

The original plan as documented in Figure 3 was revised due to the logistics of requesting official information. The research became a single phase small-scale study with two data collection methods running concurrently as represented in Figure 4. The research was conducted in iterations, moving between inductive and deductive cycles (Thomas, 2006), which supported the validity of the data, minimised researcher impact and the effect of researcher bias.

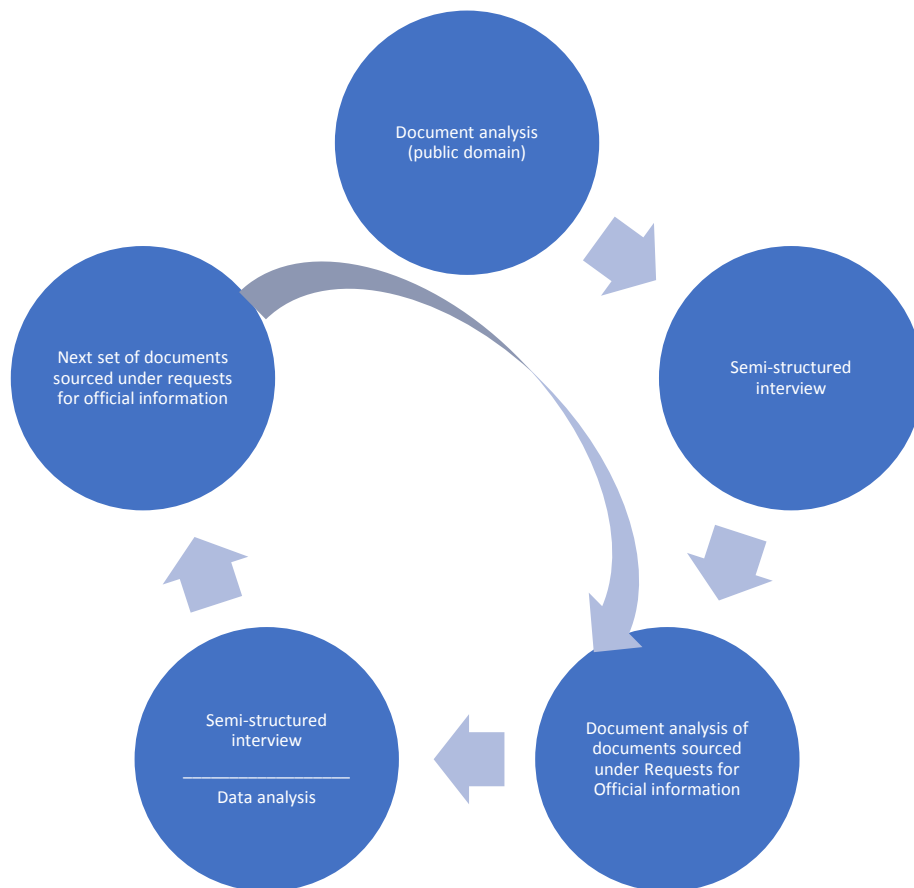


Figure 4 Amended phases for data collection

Data analysis

There were three variations of thematic analysis applied in the analysis of data in this research (Braun & Clarke, 2006; Guest, MacQueen & Namey, 2012; Thomas, 2006), resulting in six phases in the processes of analysis for this research: familiarisation with the data; open-coding; categorising; reviewing themes; defining; and reporting.

1. Familiarisation with the data.
 - a. Three separate applications were made for documents under the Official Information Act (1982). Source documents were read and re-read, then annotated by highlighting dates, people and writing in questions that were either raised or answered in the document.
 - b. Interview recordings were listened to three times before starting transcription to ensure thorough familiarity, maximising accuracy during transcription (Kvale & Brinkmann, 2015). Fillers and repetition were excluded where deletion did not impact on meaning. Then, each transcript was proofed while listening again to the recording. This close-reading checked that the act of transcription had not altered anything from what had originally been said. Multiple readings of the raw and complete data set supported the development of a coding framework.
2. Initial open coding involved assigning codes to begin to organise the data set. As new codes were identified, the data set was re-read. The aim was to generate a combination of upper-level and lower-level categories, maintaining balance between inductive and deductive analysis (Braun & Clarke, 2006; Guest et al., 2012; Thomas, 2006).
3. The data were categorised into themes which were then represented diagrammatically in terms of links to the research question. "Overlapping coding and uncoded text"

(Thomas, 2006, p.241) were not considered problematic in this research context. What was important was to return to phase two if any new codes were identified to ensure a systematic and comprehensive application of the coding framework. Once no new codes were identified, a thorough organisation of the data into themes was carried out.

4. The themes were reviewed in relation to the data set at both a micro (the coded extracts) and macro (the entire data set) level. The aim was to refine categories, look for subtopics, contradictions, and new insights. Categories were combined and a 'map' of the analysis was generated.
5. The themes were defined and named with an end aim of refining the number of categories down to 3-8 categories.
6. A report of the analysis was produced (Braun & Clarke, 2006; Thomas 2006).

Findings

This section summarises findings from the larger study and then relates these back to this paper's research question: What are the key components of a relevant research methodology for the qualitative study of an indigenous technology curricula?

The coding process involved digital highlighting and annotation by the lead researcher through the use of comments. The 45 themes that were identified have been listed in Table 1, with some explanatory notes for te reo Māori used in the themes. The codes used for the source documents are:

- GD (General documents, including New Zealand Education Gazette articles in 1999 and 2008 and publicly available documents)
- D1 (Documents 1, Request for official information; Ministry of Education, 1999-2003)
- D2 (Documents 2, Request for official information; Ministry of Education, 1999-2008)
- D3 (Documents 3, Request for official information; Ministry of Education, 2007-2009)
- I1 (Expert-participant interview one, conducted with Māhaki)
- I2 (Expert-participant interview two, conducted with Toroa)

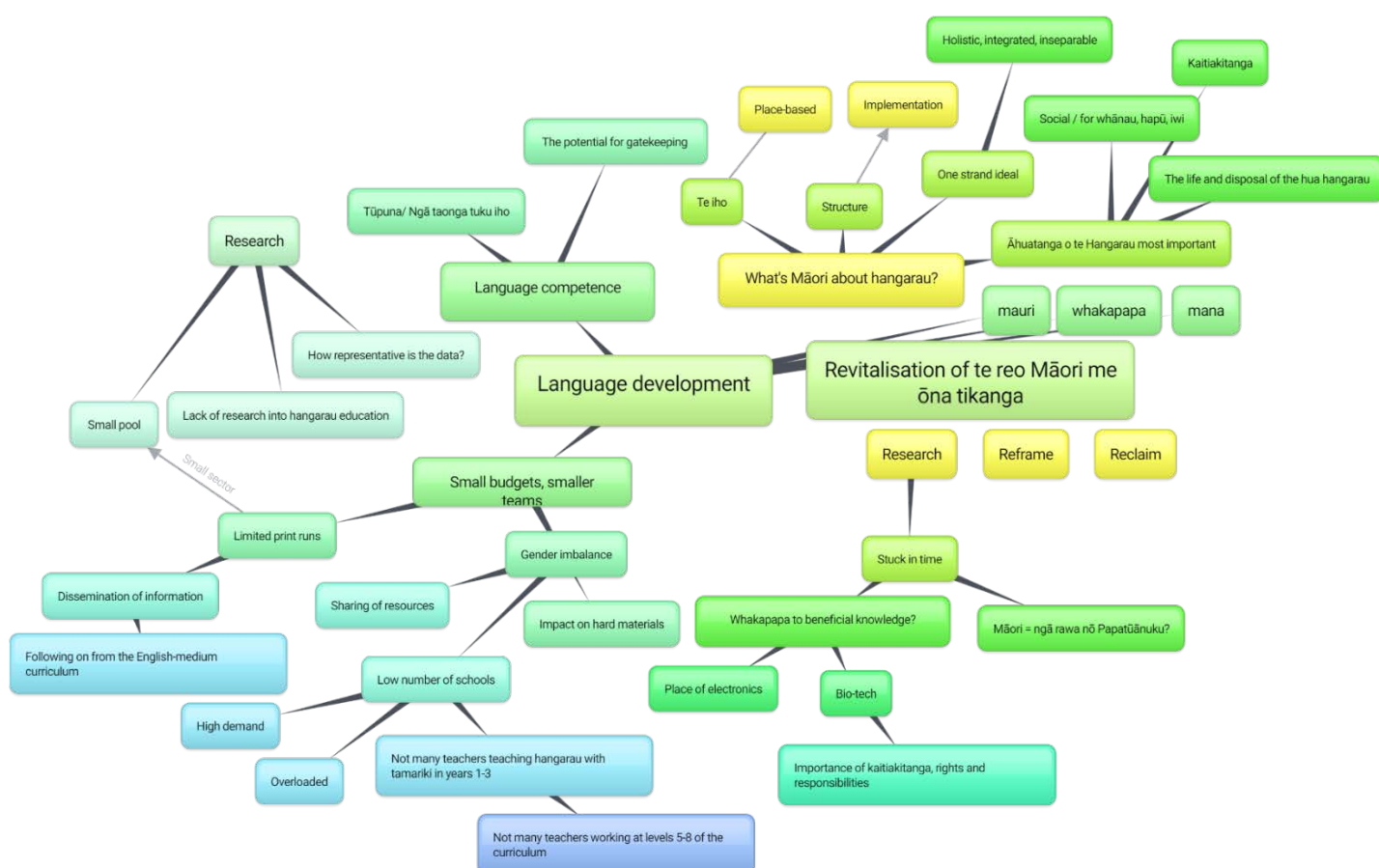
Theme	Sourced from:						Explanatory notes
	GD	D1	D2	D3	I1	I2	
1. Research		x				x	Research conducted as part of the exemplars project that had not been sourced in general documents (publicly available), until the data had pointed out its existence.
2. How representative is the data at a national level?		x				x	The main focus of the action research project was the English-medium sector. Due to the low number of Māori-medium schools, the research was informal and discussed only briefly.
3. Small pool of experts	x	x	x	x	x	x	The size of the sector has implications for many aspects of curriculum design and implementation.
4. Dissemination of information		x	x	x	x	x	Information cannot be useful if it has not been disseminated to stakeholders (related to themes 1-3, and 11)
5. Sharing of resources		x		x	x	x	
6. What's Māori about hangarau?	x	x	x	x	x	x	

Theme	Sourced from:						Explanatory notes
	GD	D1	D2	D3	I1	I2	
7. Te iho	x		x	x	x	x	The essence statement of the curriculum
8. Structure	x	x		x	x	x	Governmental expectations for the structure of the Marau Hangarau, as reflected in contracts and briefing documents provided to the curriculum teams.
9. Implementation			x	x	x	x	
10. Tūpuna	x	x	x	x	x	x	Ancestors and the place of ancestral knowledge
11. Gate-keeping and knowledge			x		x		
12. Language development	x	x	x	x	x	x	
13. Language competence	x	x	x	x	x	x	
14. Gender imbalance		x		x		x	
15. Low number of schools	x	x	x	x	x	x	Related to small sector (theme 3), differentiated by focusing on small pool (of experts / facilitators)
16. High demand	x	x	x	x	x	x	Related to themes 3-4, 15 and 17. Kaiako (teachers) were working in concurrent curriculum projects alongside the normal requirements of being a kaiako in Māori-medium.
17. Overloaded	x	x	x	x	x	x	Leading to burning out and not being able to continue on any of the projects or the need to push milestones and stagger projects. Related to all areas of the sector.
18. Years 1-3 (Taumata or levels 1-2)		x	x		x	x	Not many teachers working in hangarau with this age group, aged 5-7 years.
19. Lack of research into hangarau education	x	x	x	x	x	x	
20. ONE strand ideal		x	x			x	
21. Āhuatanga o te Hangarau most important	x		x		x	x	
22. Social focus. Hangarau practice is for family / for people first		x	x	x	x	x	Whānau = family, hapū= extended family and iwi = wider tribal group
23. Kaitiakitanga, an element of care-taking	x	x	x	x	x	x	Sustainable practices
24. The life and death of the technological product		x	x		x	x	Considering the disposal of the hua hangarau (technological product)
25. Revitalisation of Māori language and Māori practices	x	x	x	x	x	x	Te reo Māori = Māori language Tikanga Māori = Māori practices
26. Research		x	x		x	x	

Theme	Sourced from:						Explanatory notes
	GD	D1	D2	D3	I1	I2	
27. Reframe		x	x		x	x	Separated out, but themes 26-28 were identified in this was as a result of being familiar with Lesley Rameka's work in the early childhood sector. In terms of language, practices and wider Māori knowledge or mātauranga Māori.
28. Reclaim		x	x		x	x	
29. Stuck in time		x	x		x		The conflation of traditional with tradition as a response to the world in which we live
30. Governmental focus on literacy and numeracy		x	x	x	x	x	
31. Mauri		x	x	x	x	x	Refers to the life essence within everything and everyone in this world
32. Whakapapa		x	x	x	x	x	Refers to genealogical connections, placing us in relation to everything and everyone in the world
33. Mana		x	x	x	x	x	Because everything has life and everything is connected, appropriate respect and consideration must be given to all things
34. Holistic, integrated, inseparable		x	x		x	x	Strongly linked to theme 20
35. Place-based	x	x	x	x	x	x	Wally Penetito's ideas supported in the identification of this theme
36. Whakapapa to beneficial knowledge?				x	x		The significance of making connections to knowledge that is seen as beneficial
37. Is hangarau a Māori practice only when natural materials are being used?	x	x	x	x	x	x	Ngā rawa nō Papatūānuku = Materials from the environment
38. What is the place of electronics in hangarau practice?		x	x		x		Linked to theme 36, this theme emerged strongly from interview 1
39. What is the nature of Bio-technology from a Kaupapa Māori paradigm?	x		x	x		x	
40. The importance of kaitiakitanga and the balance between rights and responsibilities	x	x	x	x	x	x	Zero impact on the environment. Kaitiakitanga = stewardship, caretaking, sustainable practices
41. Not many teachers working at levels 5-8 of the curriculum		x		x		x	
42. The Māori-medium document following on from the English-medium curriculum	x	x	x		x	x	

Theme	Sourced from:						Explanatory notes
	GD	D1	D2	D3	I1	I2	
43. Limited print runs		X		X	X	X	
44. Small budgets, smaller teams	X	X	X	X	X	X	
45. Impact on hard materials			X			X	Related to the gender imbalance theme (14).

Initial groupings were made as illustrated in Figure 5, using an online mind-mapping tool. Top right were themes that were closely related to the curriculum, bottom right were socio-cultural themes. Top left were historic themes and, at the bottom left, were the political and economic themes. Problematic to this initial mapping was the lack of consistency with directionality and there needed to be an organising frame. Re-reading of the complete dataset facilitated the next step of coding, where themes were refined and thematically grouped, linking each group to the key domains targeted in the main research question. Most significant in this condensing of themes was the relevance of the data to the research questions. There was a desire to identify the themes at a literal and an interpretive level, in an in-depth description and analysis of the entire data set.



Themes were identified as stories and related to each of the guiding domains: sociocultural; historic; economic; and political, as represented in Figure 6. This figure was based on

Figure 5 Initial groupings for identified themes

McPhail's (2012, p.158) model representing the clearest and most coherent communication of the dataset. In this adapted model, relationality and prominence is represented by the domain's proximity to the Hangarau curriculum. The innermost domain represents the Hangarau curriculum and its structure and priorities. The next most significant domain is the sociocultural domain, followed by the historic, economic and political domains. All of these domains impacted on the development of the Hangarau curriculum.

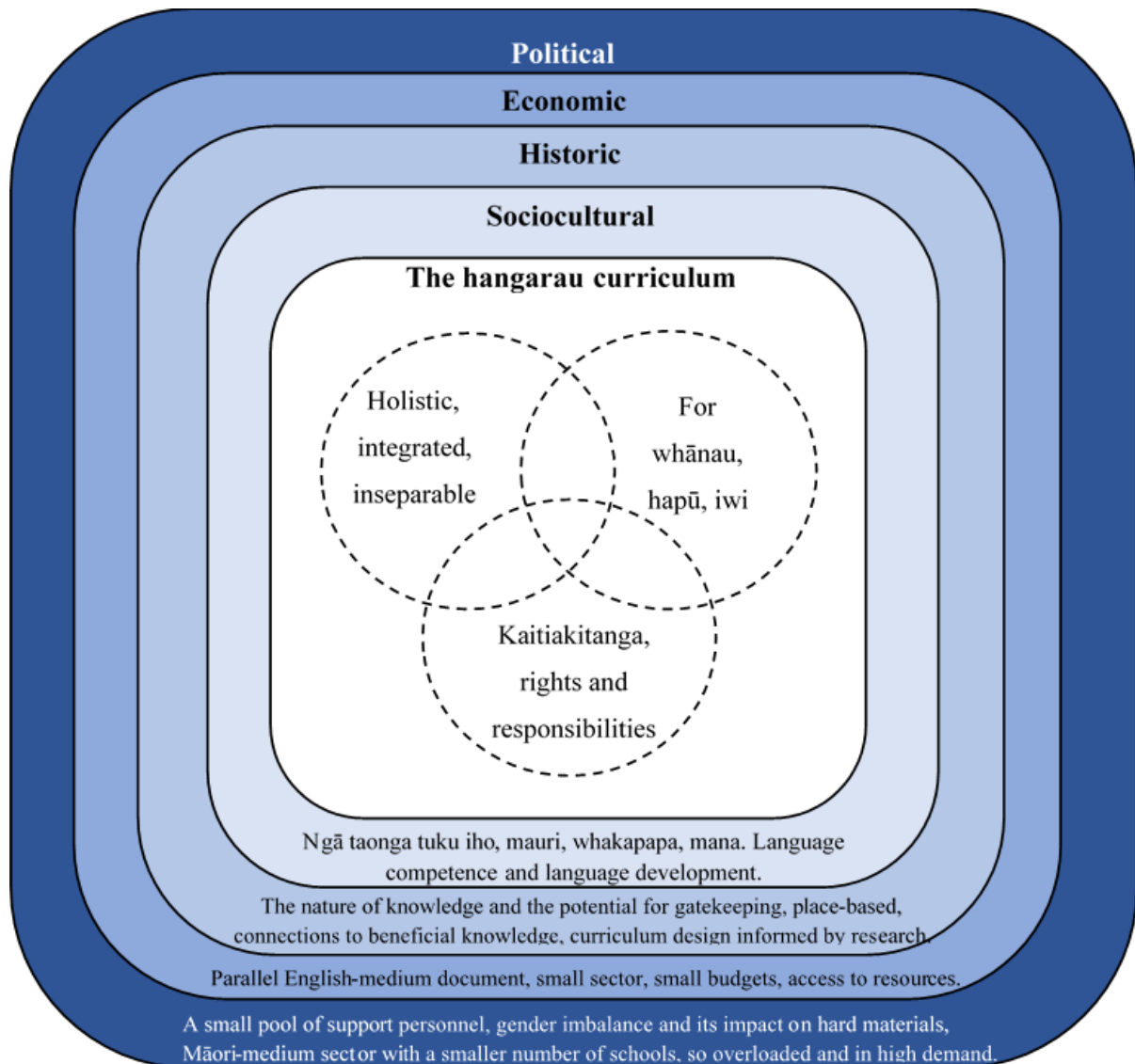


Figure 6 Key themes mapped onto the guiding domains, adapted from McPhail (2012, p.158).

As with any qualitative research, there was a subjective element in the analysis of the data, but, the methods chosen facilitated the collection of a rich dataset. Fundamentally important in this study were the ethics, in keeping with kaupapa Maori paradigm. To answer this paper's question about an appropriate methodological approach for Māori indigenous curriculum research, ethics were fundamentally important.

Ethical considerations are a duty and cannot be reduced to a case of complying with a set of rules. Te Awekotuku (1991) proposes a Māori framework for ethical research that starts with responsibility to the participants before moving wider. "A researcher's responsibility, when working with people, is to the people themselves. This responsibility transcends sponsors; these individuals must come first" (p.17). This section considers tikanga (cultural practices)

and ethics in this study, drawing from seven guidelines introduced by Mead (1996) and expanded on by Cram (2001, pp.42-50) in conversation with Mead. The guidelines have been summarised and connections between the guidelines acknowledged.

Seven Māori principles in engaging ethically with research and people

1. **A respect for people: relationship-building** as part of first contact. This principle encompasses free and prior informed consent as the result of ongoing discussion and negotiation and a participant's right to withdraw from the research without giving a reason. In terms of Hangarau in Aotearoa-New Zealand and the Māori-medium educational context, confidentiality was difficult to guarantee. The sector is small and, although there is no literature on the topic, experts involved in the development of the curriculum are widely known. To minimise the likelihood of readers inferring the identities of participants, anonymisation was used, by assigning neutral pseudonyms (that are not region-specific) to the participants' data during all stages of the research process. Names were not used when quoting the interview data.
2. **Te manaaki i te tangata: Looking after the people.** The idea that the sector is informed and benefiting from research, not just key participants and the research community. The perception that knowledge is like a conversation and travels in both directions, with researcher and participants contributing to the conversation. This involves thinking about the ways in which the research will give back to the sector, and to the people. This research sought feedback from participants, Hangarau classroom practitioners, lecturers and other researchers. The thesis outputs will be shared in a more accessible form to benefit kaiako (teachers), outlined in principle seven.
3. **Kaua e takahia te mana o te tangata: Looking after people's dignity.** Researchers are not only accountable to the research community, but also to the participants, their whanau (family) and the wider collective of Māori educators (Bishop & Glynn, 1999). As a lecturer at university and first to record the history of this document, the researcher was seen to be in a position of power. Therefore, the project procedures focused on the power and rights of the tuakana (expert-participants). The tuakana defined the extent of their participation, decided what language or combination of languages were used, and chose which questions to answer. Random selection and emailing by a third party to six out of fifteen potential expert-participants mitigated the potential loss of status for expert-participants if they chose not to participate. Though anonymity was not possible, initial decisions made by expert-participants were anonymised. In this way, the researcher did not know who had consented and who had chosen not to participate.
4. **Kia tūpato: Act with care.** There is an aspect of care that must be taken to give appropriate respect to the research topic and to the participants. There must also be awareness of taking care as a researcher, balancing the roles of outsider and insider through acknowledgement of multiple levels of being. The researcher was accountable for the selection of data collection methods consistent with the concepts of tika, pono me te aroha (fairness, truth and compassion). This research aimed for an ethical and responsible approach. In taking care, all of the other principles needed to be considered.
5. **He kanohi kitea: Literally 'the seen face'.** Although meetings had to be conducted virtually, it was important to be face-to-face in developing relationships, even if this was virtually mediated. This principle also links to the roles a researcher holds and the relationships that are maintained. If a researcher is investigating the education sector, what are their links to the sector? What is the range of their experience in the research topic? A researcher starts as a teina (younger sibling). Through the building of relationships and commitment to a range of projects, their exposure to a field grows and the knowledge they hold grows in relation to this experience.
6. **Titiro, whakarongo, kōrero: The place of looking and listening, developing an understanding before speaking.** The lead researcher first entered the education sector 21 years ago, after two years as a parent involved in Māori-medium education,

then worked as a kaiāwhina (teacher's aide), as a kaiako (teacher) and now, as a lecturer in initial teacher education. It is the appropriate time to talk. This research topic was identified as a need in 2015 but the research started in 2017 after the idea had evolved through a series of conversations with colleagues and with teachers.

7. **Kia tika te kōrero mō ngā hua: Share findings appropriately.** This principle has been adapted from Mead (1996) and Cram (2001), and was originally called: *Kaua e māhaki*. The principle focuses on the researcher's responsibility to share knowledge modestly, though maintaining and honouring community relationships. An annotated list of Hangarau resources and summaries from this study will be shared online which will be of most immediate benefit to the sector. Then, social media tools are one in a range of options that can be utilised to share the resources with schools. Dissemination in the academic sphere needs to be balanced with dissemination in the sector.

Discussion and conclusion

No previous research had been conducted into the Hangarau curriculum, however research had been conducted into other Māori-medium curricula, (Dale, 2016; McKinley, 1995; Stewart, 2007) which was explored as a starting point. Differences in the researchers' positions (Dale, 2016; McKinley, 1995; Stewart, 2007) were noted and supported the choice of method. The lack of prior research meant that it was necessary to talk to tuakana (experts) who had been involved in curriculum design. Because the events had happened up to 20 years previously, document analysis of Ministry archives were conducted via requests for Official Information. A strength of this approach is that the methods are easily replicable, but, it could be argued that this resulted in a corresponding weakness – why not select indigenous methods to conduct indigenous research? Semi-structured interviews could be called 'collaborative storying' (Bishop, 1996) or pūrākau (story-telling; Lee, 2008). Although the method chosen had an English-medium label, a key component of a research methodology for the qualitative study of an indigenous technology curriculum is talk, which comes in a range of forms. Now that the initial conversations have taken place, the method could expand into collaborative storying or a wānanga approach (critical engagement with a topic through the space of an extended meeting). The document analysis was approached as an extension to the literature review and a way of supporting the tuakana (experts) as some of the events had taken place over twenty years prior. For this reason, this paper recommends that continued requests for official information are made to support avenues for 're-entry' into the events. The use of the documents could be combined with wānanga, as in the approach of Cardno, Rosales-Anderson and McDonald (2017).

The seven principles for ethical consideration represent a Kaupapa Māori (from a Māori paradigm) approach to research. A key difference to English-medium research is the need to communicate and disseminate findings in an appropriate and beneficial way to the participants and to the wider sector. This is also desired in English-medium, but it is not a fundamental part of the research process.

Te iho o te Hangarau encapsulates the essence of Hangarau, originating from a Māori perspective and encouraging engagement with the curriculum from the places that kaiako and students connect to. The essence transitions smoothly from a more general Māori document to iwitanga (tribal-specific) perspectives in the reclamation and regeneration of new knowledge. The subject needs to be researched to inform further iterations of curriculum design and to disseminate information to the sector. Research into the curriculum precedes research into the enacted curriculum and classroom practice of Hangarau. It is the authors' hope that this paper starts a conversation about appropriate methodological approaches in the research of Hangarau and indigenous technology curricula.

References

- Bishop, R. (1996). Interviewing as collaborative storytelling. *Educational Research and Perspectives*, 24(1), 28-47.
- Bishop, R., & Glynn, T. (1999). *Culture counts: Changing power relations in education*. Palmerston North, New Zealand: Dunmore Press.
- Braun, V. & Clarke, V. (2006). *Using thematic analysis in psychology*. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp0630a>
- Cardno, C., Rosales-Anderson, N., & McDonald, M. (2017). Documentary analysis hui: An emergent bricolage method for culturally responsive qualitative research. *MAI Journal*, 6(2), 143-152. <https://doi.org/10.20507/MAIJournal.2017.6.2.4>
- Compton, V. (2001). *Developments in Technology education in New Zealand, 1993-1995: An analysis of the reflections of key participants*. (Unpublished doctoral dissertation). University of Waikato, Waikato, New Zealand.
- Cram, F. (2001). Rangahau Māori: tōna tika, tōna pono. In M. Tolich (Ed.), *Research ethics in Aotearoa New Zealand* (pp.35-52). Auckland, New Zealand: Pearson.
- Dale, H. (2016). Te whanaketanga o te wāhanga ako o te Tikanga-ā-lwi: Mai i te kore, ki te wheiao, ki te ao mārama. The development of the Tikanga-ā-lwi learning area: From nothingness, to half-light, to the full light of day. In M. Harcourt, A. Milligan, & B. Wood (Eds.). *Teaching social studies for critical, active citizenship in Aotearoa New Zealand* (pp.20-39). Wellington, New Zealand: NZCER Press.
- Danto, E. (2008). *Historical research*. New York, NY: Oxford University Press.
- De Vries, M.J. (2006). Two decades of technology education in retrospect. In M.J. De Vries & I. Mottier (Eds.). In *International handbook of technology education: Reviewing the past twenty years* (pp. 3-11). Rotterdam, The Netherlands: SENSE.
- Guest, G., MacQueen, K.M., & Namey, E.E. (2012). Introduction to Applied Thematic Analysis. In *Applied Thematic Analysis*. pp: 3-20. California, CA: SAGE.
- Jones, A. (2003). The development of a national curriculum in technology for New Zealand. *International Journal of Technology and Design Education*, 13, 83-99.
- Kvale, S. & Brinkmann, S. (2015). *Interviews: learning the craft of qualitative research interviewing* (3rd ed.). California, CA: SAGE.
- Lee, J.B.J. (2008). Ako: Pūrākau of Māori teachers' work in secondary schools. (Unpublished doctoral dissertation). The University of Auckland, Auckland, New Zealand. Retrieved from http://www.rangahau.co.nz/assets/lee_J/leej2008_phd.pdf
- Lee, K. (2011). Looking back, to look forward: Using traditional cultural examples to explain contemporary ideas in technology education. *Journal of Technology Education* 22(2), 42-52.
- McCulloch, G. (2004). *Documentary research in education, history and the social sciences*. London, UK: Routledge Falmer.
- McKinley, E.A. (1995). *A power/knowledge nexus: writing a science curriculum in Māori*. Wellington, New Zealand: He Parekereke Department of Education Victoria University of Wellington.
- McPhail, G.J. (2012). *The canon or the kids: Teachers and the recontextualisation of classical and popular music in the secondary school curriculum*. (Unpublished doctoral dissertation), The University of Auckland, Auckland, New Zealand.
- Mead, L.T.T.R. (1996). *Nga aho o te kakahu matauranga: The multiple layers of struggle, by Maori in education*. (Unpublished doctoral dissertation), University of Auckland, Auckland, New Zealand.
- Ministry of Education. (1993a). *Te Anga Marautanga o Aotearoa*. Wellington, New Zealand: Learning Media.
- Ministry of Education. (1993b). *The National Curriculum of New Zealand – A Discussion Document*. Wellington, New Zealand: Learning Media.
- Ministry of Education. (1999-2003). *Various policy and operational papers CU17/719/5; CU15/755/5: Ngā tauaromahi; Hangarau video*. Wellington, New Zealand: Documents released under request for official information 1100564.
- Ministry of Education. (1999-2008). *Various policy and operational papers CU17/812/5; CU15/2227/5; CU17/846/5; 1999 Hangarau implementation; 2006 marau redevelopment*.

- Wellington, New Zealand: Documents released under request for official information 1139624.
- Ministry of Education. (2007-2009). *Various policy and operational papers CU15/3237/5; CU15/344/5; Te Raweke Ira; NAMSATT*. Wellington, New Zealand: Documents released under request for official information 1118980.
- Ministry of Education. (2008). *Te Marautanga o Aotearoa*. Wellington, New Zealand: Learning Media.
- Ministry of Education. (2009, Oct 29). *New Zealand Education Gazette*, (157). pp.3787-3830. Wellington, New Zealand: Department of Internal Affairs.
- Official Information Act, (1982). Retrieved from: <http://www.legislation.govt.nz/act/public/1982/0156/latest/DLM64785.html>
- Stewart, G.M. (2007). *Kaupapa Māori science* (Unpublished doctoral dissertation). The University of Waikato, Hamilton, New Zealand. Retrieved from <https://hdl.handle.net/10289/2598>
- Te Awekotuku, N. (1991). *He tikanga whakaaro: Research ethics in the Maori community. A discussion paper*. Wellington, New Zealand: Manatu Maori.
- Thomas, D.R. (2006, June). A general inductive approach for analyzing qualitative evaluation data. *American Journal of Evaluation*, 27(2), 237-246. <https://doi.org/10.1177/1098214005283748>
- Williams, P.J. (2018). Technology education: history of research. In M.J. de Vries (Ed.), *Handbook of technology education* (pp.85-99). Delft, The Netherlands: Springer.

Design & Technology and Computer Science in the CAMAU Project: The Genesis of Learning Progression in the New Curriculum for Wales.

David Morrison-Love, Peter Donaldson, Janine Barnes



David Morrison-Love
University of Glasgow
UK
david.morrison-love@glasgow.ac.uk



Peter Donaldson
University of Glasgow
UK
peter.donaldson.2@glasgow.ac.uk



Janine Barnes
University of Wales
UK
janine.barnes@uwtsd.ac.uk

ABSTRACT

Wales is currently undertaking significant curricular reform following a systematic review of the country's education system (Donaldson, 2015). As frameworks that reflect evolving societal demands and shape learning experiences, curricula occupy a powerful and integral place in Education. Despite this, it is not always clear that they support pupils' learning in ways that pay attention to research evidence and classroom experience. The CAMAU Project (University of Glasgow & University of Wales Trinity Saint David), designed to address this concern, was commissioned by the Welsh Government to support the process of radical, evidence-based curricular reform. Developed around the Integrity Model of Change (Hayward & Spencer, 2010), it brings together researchers, policy-makers and Welsh teachers as co-developers of learning progressions using participatory research methods (Bergold & Thomas, 2012) and the principle of subsidiarity (Donaldson, *ibid*). These frameworks will support planning and formative assessment by describing learning journeys for Welsh pupils aged 3 to 16. This paper describes the CAMAU project and discusses selected findings from research, policy and practice in the first phase of developing progression frameworks for Design and Technology, and Computer Science. Reviews of research and policy presented in Hayward et al (2018) were undertaken using the 'Knowledge to Action' method (Khangura et al, 2012). A discussion of this evidence suggests that ideas of 'the process of abstraction', 'systems and mental models' and 'quantity, level of integration and complexity of factors considered' may be important in learning progression. From the perspective of practice, more open-ended pupil tasks appear to support teachers better in the early stages of thinking through progression. When initially describing learning progression, many teachers focused on describing particular task requirements or the independent use of skills, rather than the underlying conceptual understanding. Initial descriptions were more skill-based with less agreement about the knowledge required to support progression.

Keywords: Learning Progression, Design & Technology, Computing Science, Curriculum for Wales, Research, Policy and Practice, CAMAU Project.

Introduction

While it can be safely assumed that representations of progression have always featured in the curricula of formal education, recent interest points to a growing critical recognition of the importance of progressions for learning and teaching. Heritage (2008), for example, observes that statements of curricular standards often do not provide a clear picture of learning progression. She argues that, were this to be addressed, teachers could gain greater clarity about how learning progresses in particular domains and engage in more effective formative assessment. Similar concerns are raised by Black et al (2011) who argue for ‘evidence-based road maps’ of the journey through which learning would typically move in order to support classroom pedagogy and assessment. Many examples of such approaches can be found for Science Education, often framed around ‘big ideas’ (Harlen, 2010) and provide structures for refining curricula in ways that can deepen our understanding of what is truly important for future learning.

There are some indications that areas of Technology Education may be starting to explore this type of thinking. In the United States, the National Research Council have identified nine big ideas for engineering organised by knowledge, skills and habits of mind (NCR, 2009). More recently in the United Kingdom, Barlex & Steeg (2017), propose big ideas ‘about’ the fundamental nature of design and technology and big ideas ‘of’ design and technology including materials, manufacture, functionality, design, and critique. Similar work in New Zealand has been undertaken by Bell, Tymann and Yehudai (2018) to identify ten big ideas for K12 Computer Science curricula. Despite such efforts to key into what matters, associated evidence about how learning progresses in Design & Technology (D&T) and Computer Science (CS) remains sporadic and limited in comparison to Science (Hayward et al, 2018). Given the concerns of Heritage (2008) and others, this calls into question the extent to which representations of progression in our existing curricula are truly evidenced-based.

Learning progression is complex and it can be conceptualised and explored in a range of ways (Lobato & Walters, 2017). A pedagogical or curricular teaching sequence, for example, may not necessarily reflect increasing sophistication in pupil learning. More broadly, studies that explore and seek to understand learning do not necessarily contribute readily to understanding what more complex learning looks like in different areas of learning. The CAMAU Project (Welsh for ‘Steps’) is a 3-year project commissioned by the Welsh Government that places learning progression at the heart of the new curriculum for Wales. Around 120 teachers, 20 policy leads and 20 researchers participated in this project over an extended period. Through the co-construction of evidence-informed progression frameworks for all six ‘areas of learning and experience’ (AoLEs) in the new Curriculum for Wales (Donaldson, 2015), the project seeks to develop and share understanding of how curriculum, progression and assessment might be described and enacted in Wales to focus upon learning through better alignment between research, policy and practice.

This paper reports upon the first phase of developing progression frameworks for D&T and CS as part of the work undertaken in the Science & Technology AoLE. Firstly, it describes the work of the CAMAU Project in the context of Welsh educational reform, the socio-cultural grounding adopted, and the methods developed to support the authentic co-construction of a national, learning-centred curriculum. Secondly, it uses a framework of selected findings from the summaries of research and policy presented in the recent CAMAU Research Report (‘Learning About Progression’, Hayward et al, 2018) to explore evidence from teachers’ early thinking through of progression for aspects of D&T and CS. The paper concludes by drawing together implications.

The Context and Starting Point for the CAMAU Project

There are international, national and developmental features to the context of the CAMAU work on learning progression. The Welsh education system is currently undergoing significant systemic change initiated through Welsh Government concern about a perceived fall in educational standards (Estyn 2014, HMCI Wales 2012, Welsh Government 2012), evidenced by weak performance in international PISA tests (Wheater et al. 2013). A review of the National Curriculum (Donaldson 2015) resulted in recommendations on the design of a new, purpose driven curriculum which have been accepted in full by the Welsh Government (2015). With respect to the CAMAU Project, key recommendations pertained to curricular organisation, progression and subsidiarity:

- A curriculum organisation into six areas of learning and experience (Languages, Literacy & Communication, Maths & Numeracy, Expressive Arts, Health & Well-Being, Science & Technology and Humanities).
- A move away from key stage standards towards progression steps. These steps are comprised of achievement outcomes that support forward-facing formative assessment and progression rather than provide backward-facing summaries (Donaldson, 2015:114).
- Adherence to the principle of 'subsidiarity', which is defined as "commanding the confidence of all, while encouraging appropriate ownership and decision making by those closest to the teaching and learning process" (Donaldson, 2015, p.14). In contrast to more top-down approaches (Kelly, 2009), this places teachers at the heart of developing the Curriculum for Wales with the Welsh Government identifying and funding around 70 schools with particular expertise to participate.

The Science & Technology AoLE brings together aspects of learning traditionally defined in subjects such as Physics, Chemistry, Biology, Design & Technology and Computer Science. Notably, it is the first time that aspects of CS have been recognised as a core area in the Welsh Curriculum across the ages of 3-16. This AoLE not only fosters a rich and diverse learning space in the curriculum, it provides opportunities to think through the interrelationships between learning in different areas. Though some levels of distinction were ultimately retained, early and significant thinking in this AoLE considered whether these areas could or should be more fully integrated.

In the year prior to the start of the CAMAU Project, the Science & Technology AoLE also developed descriptions of 'What Matters' for learning. What matters align with the curriculum purposes and can be understood as those things that are most important for an educated Welsh citizen to know, understand and be able to do by the age of 16. What Matters for Science & Technology was initially set out in eight statements and rationales providing a series of starting points for the development of progression frameworks in the CAMAU Project. Over time, the iterative development process merged societal and environmental impacts of science and technology across the other areas and design thinking and engineering were combined which resulted in six what matters statements. Two were related to Design and Technology and Computer Science which are:

- WM 2 Design thinking and engineering are technical and creative endeavours intended to meet society's needs and wants
- WM 6 Computation applies algorithms to data in order to solve real-world problems

The Theoretical Grounding of the CAMAU Project

The CAMAU Project was designed to support a complex process of collaborative development involving researchers, policy makers and teachers in the context of large-scale systemic change. It is concerned not only with the development of progression frameworks, but also the nature of the collaborative processes from which these emerged. Fundamentally, the project is grounded upon socio-cultural theories of understanding (Rosa & Montero, 1990; John-Steiner & Mahn, 1996) and the principle of subsidiarity (OECD, 2017; Donaldson, 2015). This shaped activity at all levels of the project including the longitudinal work undertaken within Science & Technology. From this stance, the evidence and expertise brought to bear in creating learning progressions is mediated and developed through the sustained and culturally situated social interactions of the participating researchers, policy makers and teachers. It is through these interactions that understandings of learning progression collectively emerge. Towards this end, the integrity model of change (Hayward et al, 2010) was adopted to frame ways of exploring the nature of change processes in the development of progression frameworks for Wales. This model suggests that sustainable change requires that educational, personal and professional, and systemic integrity are maintained and appropriately aligned throughout (Hayward et al, *ibid*).

AoLE Participants & Overall Project Design

The Science & Technology AoLE consisted of 2 policy leads, 3 researchers and around 20 teachers, who met monthly. This varied sometimes in response to the changing nature of tasks and, over time, involved several external subject experts. The CAMAU Project is designed around three large-scale iterative activity phases. Phase 1 gathered evidence about learning progression in relevant subject areas from research, international policy and practice for each of the AoLEs. In Science & Technology, this allowed a shared understanding of progression in areas such as energy, designing and making, and algorithms to develop among researchers, teachers and AoLE policy leads. Critically, it provided a basis from which progression frameworks could be collaboratively developed in phase 2. Phase 3 will gather and analyse empirical evidence to support the iterative refinement of progression frameworks and the wider implementation of the curriculum across Wales. As previously stated, this paper discusses findings for D&T and CS from Phase 1.

Methodology

Two main methodologies were developed to gather evidence for D&T and CS in Phase 1. Reviews of research and international curricular policy were undertaken and a participatory activity was developed to explore teachers' initial conceptions in thinking through learning progression.

To produce a dependable summary of evidence for D&T and CS (Grant & Booth, 2009), research and policy reviews were carried out using the 'Knowledge to Action' method described by Khangura et al, (2012). This eight-stage approach used is described in Hayward et al (2018) and involved identifying, screening, analysing and summarising research and several national curricular frameworks using guiding questions about how progression was conceptualised and represented. The identification and screening process revealed that despite large numbers of studies providing insights into aspects of learning in D&T and CS, relatively few considered the way in which learning changes over time. The research and policy reviews were supported by six Professorial Consultants and by the project's National and International Advisory Group. Summaries of the findings from this process, presented in Hayward et al (2018), are discussed in the following section of this paper.

To elicit provisional evidence and build knowledge about teachers' existing conceptions of learning progression in their subject areas, a four-stage participatory research task was

designed (Bergold & Thomas, 2012). Small groups of teachers with a shared subject interest were established. As far as possible, each group comprised three or four teachers from both primary and secondary settings. In the first stage, each group critically reviewed a range of possible investigative methodologies and either selected the one they considered most appropriate or developed their own with support from researchers. In the second stage, teachers identified examples of pupil classroom work that covered a range of knowledge, concepts and skills that they thought were important. Given that the mental models of how learners understanding develops held by teachers are often fragile, incomplete and challenging to make explicit (Carpenter, et. al, 1988; Fennema, et. al. 1996), real classroom work served as a culturally aligned mediating artefact in the process of thinking through progression. The third stage involved comparative analysis of this pupil work by the teachers, scaffolded using stimulus questions. During the final stage, teachers ordered and summarised the successively more complex shifts in learning they had identified. All three groups featured in this paper (CS, n=2, D&T, n=1) were asked to compare pupils' work at three different stages of a learning journey. Rather than seeking to establish actual learning progressions, this activity gave insight into teachers' initial conceptualisations of learning shifts to support the work in phases 2 and 3 of the CAMAU project. Staged task outputs, summaries of teacher discussions, agendas and observational reflections provided evidence for this process.

Phase 1: Discussion of Ideas from Research and Policy

The summaries of research and policy evidence of learning progression in D&T and CS from Phase 1 are presented in Hayward et al (2018). The discussion presented here highlights preliminary findings from on-going work that will be discussed more fully in subsequent publications.

For each of these subject areas, there were few studies reviewed with a primary focus upon learning progression or trajectories (e.g. Kimbell, 1994; Compton & Harwood, 2003; Compton & Harwood, 2005; McLaren & Stables, 2008; Jones, 2009; Danos & Norman, 2011; Seiter & Foreman, 2013; Rich et al, 2017). The most significant empirical basis was found across the work of Compton, Compton and Harwood which, at the time, supported reforms to the New Zealand curriculum. Other studies, such as those comparing novice/less developed and expert/more developed learning (e.g. Teague, 2015; Morrison-Love, 2015) or approaches to deeper learning (Grover et al, 2015; Bocconi et al, 2016), contribute to parts of the developing picture of learning progression in both D&T and CS. More recent studies of this type are beginning to shed light on factors that support greater success in different forms of learning (e.g. Bartholomew & Strimel, 2018; Rich et al, 2018; Wong & Jiang, 2018; Rich et al, 2019). Some studies from the learning sciences similarly provide insights into aspects of CS such as learning to program (e.g. Wyeth, 2008). Variations in the types of studies reviewed make structured cross-comparison challenging. However, attention can be usefully drawn to ideas of 'the process of abstraction', 'systems and mental models' and 'quantity, level of integration and complexity of factors considered' that appear in ideas of progression for both D&T and CS.

The process of abstraction in those studies reviewed can be seen to involve learner and different system/artefact representations, and some form of transactional process. In computational thinking, this can involve learners establishing patterns and levels of interaction between computers and users (Colburn & Shute, 2007; Hill et al, 2008) or between abstract concepts and how they are implemented in a specific digital system or application (Connor et al, 2017). Understanding similar interactions in developing technical solutions is likely also to be important for learning in D&T. Particularly for ideation, sketching/modelling and testing, pupils' ability to utilise different degrees and forms of abstraction in ways that foster a more expert and connected understanding is important (e.g. Mioduser et al, 2007; Haupt, 2018). Unlike areas of maths and science that tend to proceed from more concrete experiences to

abstract ideas, the role of abstraction may be more varied in moving towards sophisticated forms of understanding in technology. For example, the development of solutions often involves the generation of abstract ideas and designs that gradually become more detailed as they move towards their final concrete physical or digital forms (Morrison-Love, 2017). Examples of shifts that involve different uses of abstraction can also be identified in curricular policy (Table 1).

Aspect	Design and Technology	Computer Science
Development of Solutions	<p>Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.</p> <p>Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.</p> <p>Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.</p> <p><i>United States Engineering Design Next Generation Science Standards K2, K3-5 and Middle School</i></p>	<p>People develop programs collaboratively and for a purpose, such as expressing ideas or addressing problems.</p> <p>People develop programs using an iterative process involving design, implementation and review. Design often involves reusing existing code or remixing other programs within a community.</p> <p>People design meaningful solutions for others by defining a problem's criteria and constraints, carefully considering the diverse needs and wants of the community and testing whether the criteria and constraints were met.</p> <p><i>United States K12 Computer Science Framework Program Development Progression Grade 2, 5 and 8.</i></p>

Table 1: Progression in Curricular Policy Involving Working Abstraction

It is also proposed in CS, that more sophisticated learning depends upon pupils developing an appropriate mental model of the computer as a 'notional machine' (Du Boulay, 1986; Ben-Ari, 2001; Sorva, 2013). Moreover, it is suggested that this is supported better by knowledge at the level of structure and actions than it is by lower level knowledge of, for example, bit manipulation. Arguably a form of systems model, this is important for developing reasoning. Whilst the notional machine in CS develops around largely fixed parameters and affordances, more sophisticated reasoning about differing technical artefacts and outcomes in D&T also requires a sufficiently developed mental model (see: 'Analytical Reflection' in Morrison-Love, 2015). Similarly, such mental models often encompass knowledge about structure and action in technical solutions and foster a more technical understanding of how things work, rather than a scientific understanding of why things work (Banks & Plant, 2013). Examples of progression from curricula involving this type of understanding are shown in Table 2.

Aspect	Design and Technology	Computer Science
--------	-----------------------	------------------

<p>Physical and Digital Systems</p>	<p>explore and use mechanisms [for example, levers, sliders, wheels and axles], in their products.</p> <p>understand and use mechanical systems in their products [for example, gears, pulleys, cams, levers and linkages]</p> <p>understand how more advanced mechanical systems used in their products enable changes in movement and force.</p> <p><i>English Design and Technology National Curriculum Key Stage 1, 2 and 3</i></p>	<p>Demonstrates an understanding that computers take information as input, process and store that information and output the results.</p> <p>Describes the purpose of the processor, memory and storage and the relationship between them.</p> <p>Demonstrates an understanding of the von Neumann architecture and how machine code instructions are stored and executed within a computer system.</p> <p><i>Scottish Technologies Computing Science Curriculum Organiser 1st, 2nd and 3^d level Benchmarks</i></p>
-------------------------------------	---	--

Table 2: Progression in Curricular Policy Involving Mental Models

Research evidence in both D&T and CS reveals something of the quantity, level of integration and complexity of factors considered in more sophisticated learning. In designing technical and coding solutions, pupils appear able to actively integrate or ‘operationalise’ a greater number of different types of factors at more developed stages of learning (Jones, 2009; McLaren & Stables, 2008; Morrison-Love, 2015; Aivaloglou et al., 2017; Franklin et al., 2017). Moreover, they are increasingly able to evaluate these against particular conditions, constraints and affordances. These shifts are reflected to some extent in examples of curricular policy (Table 3).

Aspect	Design and Technology	Computer Science
<p>Evaluation of Design</p>	<p>... evaluate ideas and designed solutions against identified criteria for success, including environmental sustainability considerations.</p> <p>They suggest criteria for success, including sustainability considerations and use these to evaluate their ideas and designed solutions.</p> <p>They develop criteria for success, including sustainability considerations, and use these to judge the suitability of their ideas and designed solutions and processes.</p> <p><i>Australian Curriculum Design and Technology Sequence of</i></p>	<p>They also evaluate user interfaces in relation to their efficiency and usability.</p> <p>.. they develop programs considering human-computer interaction (HCI) heuristics.</p> <p>They apply design principles and usability heuristics to their own designs and evaluate user interfaces in terms of them.</p> <p><i>New Zealand Computational Thinking for Digital Technologies Progression Progress Outcomes 4, 5 and 6</i></p>

	<i>Achievement from Years 3 and 4, 5 and 6 and 7 and 8</i>	
--	--	--

Table 3: Progression in Curricular Policy Involving Quantity, Level of Integration & Complexity

Phase 1: Selected Insights from Practice

The first group examined a small sample of different pupil work that lacked variation within particular task outcomes to support them in thinking about progression in CS. After some initial difficulties selecting work to examine and discuss, they mainly focused on the relative difficulty of different programming related tasks. Although descriptions produced were limited and high-level there was some indication that the variety and complexity of programming constructs used was a key discriminator between novices at different stages of development. The second group thinking about progression in IT using work from a single tightly scaffolded multimedia development task and focused upon identifying skills pupils could successfully carry out independently at two points in time rather than how learning had shifted. In thinking through progression at the beginning of phase 1 both Computing groups found it a challenge to focus on describing shifts in learning, focusing respectively on either task completion or skills independently used by learners.

By contrast, the D&T group analysed a more open-ended mascot design task completed by pupils at a range of ages and stages and were quickly able to focus on describing learning progression. The statements generated were more numerous and finer grained and there was clear evidence of describing progression in the ability to consider and integrate a gradually more complex set of design and technology factors over time. These included moving from focusing on just the visual appearance of an idea to considering factors such as scale, dimension and materials and techniques that would aid in the process of constructing the mascot. There was also some evidence of consideration of abstraction with the learning progression indicating an expectation that novices would increasingly reduce the level of abstraction in their design idea to increasingly include details of how it could be implemented in a concrete physical form in the construction phase.

The Computing and D&T groups experiences suggests that examining pupil work generated by several closed or tightly scaffolded tasks may offer less discrimination between stages of learning than a single open-ended task with minimal teacher scaffolding carried out across a range of age groups. This echoes the approach to generating evidence of levels of achievement employed in Technology by the New Zealand National Education Monitoring Project (2008); suggesting analysis of a range of samples of work and/or pupil performance in open-ended tasks is also beneficial for developing teachers understanding of progression in learning.

Feedback from both the AoLE leads and members indicated that they valued the exercise and suggested a future role for it to help support a shift in other teachers understanding from an assessment standard driven to a progression orientated view of learning and teaching.

Conclusions & Implications

This paper described the work of the CAMAU Project and provided insights from evidence in research, policy and practice from the first stages of understanding and thinking through progression for D&T and CS. Some aspects such as the process of abstraction, systems and mental models and factors, integration and complexity appear to play role in each area, but there remains a need to understand better the nature of and approaches to developing teachers understanding of learning progression. Not only will this further support classroom

learning and formative assessment, but it offers new and significant potential for how we understand and conceptualise D&T and CS as important areas of learning going forward.

References

Australian Curriculum, Assessment and Reporting Authority (ACARA). (2016). Technologies: Sequence of Achievement. Retrieved from http://docs.acara.edu.au/resources/Technologies_Sequence_of_achievement.pdf

Aivaloglou, E., Hermans, F., Moreno-León, J. & Robles, G. (2017). A Dataset of Scratch Programs: Scraped, Shaped and Scored. In *Proceedings of the 14th International Conference on Mining Software Repositories, MSR '17* (pp. 511-514). Piscataway, NJ: IEEE Press.

Banks, F., Plant, M. (2013). Transferring Knowledge Versus Knowledge Through Technology Education. In Middleton, H. E. & Baartman, L. K. J. (Eds.), *Transfer, Transitions and Transformations of Learning*. Springer (pp. 23–37), Rotterdam, Netherlands: Sense Publishers.

Barlex, D. & Steeg, T. (2017). Big Ideas in Design & Technology: A Working Paper. Retrieved from <https://dandfordandt.files.wordpress.com/2017/05/big-ideas1.pdf>

Bartholomew, S.R., Strimel, G.J. and Yoshikawa, E. (2018). Using Adaptive Comparative Judgment for Student Formative Feedback and Learning During a Middle School Design Project. *International Journal of Technology and Design Education*, 29(2), 1-23. <https://doi.org/10.1007/s10798-018-9442-7>

Bell, T., Tymann, P. and Yehudai, A. (2018). The Big Ideas in Computing Science for K-12 Curricula. European Association for Theoretical Computer Science. No. 124. Retrieved from <http://bulletin.eatcs.org/index.php/beatcs/article/view/521>

Ben-Ari, M. (2001). Constructivism in Computer Science Education. *Journal of Computers in Mathematics and Science Teaching*, 20(1), 45-73.

Bergold, J. and Thomas, S. (2012). Participatory research methods: A methodological approach in motion. *Forum: Qualitative Social Research*, 13(1), 191-222.

Black, P., Wilson, M. and Yao, S.Y. (2011). Road maps for learning: A guide to the navigation of learning progressions. *Measurement: Interdisciplinary Research & Perspective*, 9(2-3), 71-123. <https://doi.org/10.1080/15366367.2011.591654>

Bocconi, S., Chiocciariello, A., Dettori, G., Ferrari, A., Engelhardt, K., Kampylis, P., & Punie, Y. (2016). Developing Computational Thinking in Compulsory Education: Implications for Policy and Practice. JRC Science for Policy Report. European Commission. Retrieved from http://publications.jrc.ec.europa.eu/repository/bitstream/JRC104188/jrc104188_computhinkreport.pdf

Carpenter, T., Fennema, E., Peterson, P., & Carey, D. (1988). Teachers' Pedagogical Content Knowledge of Students' Problem Solving in Elementary Arithmetic. *Journal for Research in Mathematics Education*, 19(5), 385-401. doi:10.2307/749173

Colburn, T., & Shute, G. (2007). Abstraction in computer science. *Minds and Machines: Journal for Artificial Intelligence, Philosophy and Cognitive Science*, 17(2), 169-184. <http://dx.doi.org/10.1007/s11023-007-9061-7>

- 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. <https://doi.org/10.1023/B:ITDE.0000039567.67842.c3>
- 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(3), 253-287. <https://doi.org/10.1007/s10798-004-5401-6>
- Connor, R., Cutts, Q. and Robertson, J. (2017). Keeping the Machinery in Computing Education. *Communications of the ACM*, 60(11), pp.26-28. Retrieved from <https://cacm.acm.org/magazines/2017/11/222181-keeping-the-machinery-in-computing-education/fulltext>
- Danos, X. and Norman, E.W.L. (2011). Continuity and Progression in Graphicacy. In Norman, E.W.L. & Seery, N, (Eds.), *IDATER Online Conference: Graphicacy and Modelling 2010* (pp. 103-119). Loughborough: Design Education Research Group, Loughborough Design School. Retrieved from https://dspace.lboro.ac.uk/dspace-jspui/bitstream/2134/9023/1/Norman-ch-5-IDATER_Online_BOOK%5B1%5D.pdf
- Donaldson G. (2015). Successful Futures: Independent Review of Curriculum and Assessment Arrangements in Wales. Welsh Government: Cardiff. Retrieved from <https://gweddill.gov.wales/docs/dcells/publications/150225-successful-futures-en.pdf>
- Du Boulay, B. (1986). Some Difficulties of Learning to Program. *Journal of Educational Computing Research*, 2(1), 57-73. <https://doi.org/10.2190/3LFX-9RRF-67T8-UVK9>
- Estyn. (2014) The Annual Report of HM Chief Inspector of Education and Training in Wales 2013-2014. Retrieved from <http://www.assembly.wales/laid%20documents/gen-ld10093%20-%20the%20annual%20report%20of%20her%20majestys%20chief%20inspector%20of%20education%20and%20training%20in%20wales%202013-2014/gen-ld10093-e.pdf>
- Franklin, D., Skifstad, G., Rolock, R., Mehrotra, I., Ding, V., Hansen, A., ... Harlow, D. (2017). Using Upper-Elementary Student Performance to Understand Conceptual Sequencing in a Blocks-based Curriculum SIGCSE. *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, 231-236. doi=3017680.3017760
- Fennema, E., Carpenter, T. P., Franke, M. L., Levi, L., Jacobs, V. R. & Empson, S. B. (1996). A Longitudinal Study of Learning to use Children's Thinking in Mathematics Instruction. *Journal for Research in Mathematics Education*, 27(4), 403-434.
- Grant, M. J., Booth, A. (2009). A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies: *Health Information & Libraries Journal*, 26(2), 91–108. doi: 10.1111/j.1471-1842.2009.00848.x.
- Grover, S., Pea, R., & Cooper, S. (2015) Designing for deeper learning in a blended computer science course for middle school students, *Computer Science Education*, 25(2), 199-237, DOI: 10.1080/08993408.2015.1033142
- Harlen, W., (2018). *The Teaching of Science in Primary Schools* (7th ed.) London, New York: Routledge.
- Hayward, L. & Spencer, E. (2010). The Complexities of Change: Formative Assessment in Scotland. *Curriculum Journal*, 21(2), 161-177. <https://doi.org/10.1080/09585176.2010.480827>

- Haupt, G. (2018). Hierarchical Thinking: A Cognitive Tool for Guiding Coherent Decision Making in Design Problem Solving. *International Journal of Technology and Design Education*, 28(1), 207–237. <https://doi.org/10.1007/s10798-016-9381-0>
- Hayward, L., Jones, D. E., Waters, J., Maraka, M., Morrison-Love, D., Spencer, E., ... Wardle, G. (2018). CAMAU Project: Research Report (April 2018). Project Report. University of Glasgow, Glasgow. Retrieved from https://www.gla.ac.uk/media/media_587517_en.pdf
- Heritage, M. (2008). Learning progressions: Supporting instruction and formative assessment. Council of Chief State School Officers (CCSSO). Retrieved from <http://www.k12.wa.us/assessment/ClassroomAssessmentIntegration/pubdocs/FASTLearningProgressions.pdf>
- Higgins, S., Hayward, L., Livingston, K., & Wyse, D. (2017). A Curricular Lens on Equity and Inclusion: Using Bernstein to Articulate 'Supercomplexity'. *The Curriculum Journal*, 28(3), 303–304. <https://doi.org/10.1080/09585176.2017.1341106>
- Higgins, S., Hayward, L., Livingston, K., & Wyse, D. (2016). Knowledge and the Curriculum: A Recurring Issue. *The Curriculum Journal*, 27(4), 427–429. <https://doi.org/10.1080/09585176.2016.1244330>
- Hill, C. (2014). Computational Thinking Curriculum Development for Upper Elementary School Classes. *Proceedings of the Tenth Annual Conference on International Computing Education Research* (pp.151–152), ICER '14. New York, USA: ACM. Retrieved from <https://dl.acm.org/citation.cfm?id=2632327>
- HMCI Wales (2012). *The Annual Report of Her Majesty's Chief Inspector of Education and Training in Wales 2011-12*, Cardiff: Estyn. Retrieved from <http://www.assembly.wales/Laid%20Documents/GEN-LD9253%20-%20The%20Annual%20Report%20of%20Her%20Majesty%E2%80%99s%20Chief%20Inspector%20of%20Education%20and%20Training%20in%20Wales%202011-2012-12032013-243903/gen-ld9253-e-English.pdf>
- John-Steiner, & V., Mahn, H., (1996). Sociocultural Approaches to Learning and Development: A Vygotskian Framework. *Educational Psychologist*, 31(3-4), 191–206.
- Jones, A. (2009). Towards an Articulation of Students Making Progress in Learning Technological Concepts and Processes. In Jones, A. & de Vries, M. (Eds.). *International Handbook of Research and Development in Technology Education, International Technology Education Studies*. Sense Publishers (pp. 407-417). Rotterdam, Netherlands.
- K-12 Computer Science Framework Steering Committee. (2016). K-12 Computer Science Framework Statements by Progression. Retrieved from <https://k12cs.org/framework-statements-by-progression/>
- Kelly, A.V. (2009). *The Curriculum, Theory and Practice* (6th ed.). London: SAGE Publications Ltd.
- Kimbell, R. (1994). Progression in Learning and the Assessment of Children's Attainments in Technology. *International Journal of Technology and Design Education*, 4(1), 65-83. <https://doi.org/10.1007/BF01197584>
- Khangura, S., Konnyu, K., Cushman, R., Grimshaw, J. & Moher, D. (2012). Evidence Summaries: The Evolution of a Rapid Review Approach. *Systematic Reviews*, 1(10), 1-9. doi:10.1186/2046-4053-1-10

- Lobato, J. & Walters, C. D. (2017). A Taxonomy of Approaches to Learning Trajectories and Progressions. *Compendium for Research in Mathematics Education*. Reston, VA: National Council of Teachers of Mathematics.
- McLaren, S. V. and Stables, K. (2008). Exploring key Discriminators of Progression: Relationships between Attitude, Meta-Cognition and Performance of Novice Designers at a time of Transition. *Design Studies*, 29(2), 181-201.
- Mioduser, D., Levy, S. T., Talis, V. (2009). Episodes to Scripts to Rules: Concrete-Abstractions in Kindergarten Children's Explanations of a Robot's Behavior. *International Journal of Technology and Design Education* 19(1), 15-36.
- Morrison-Love, D. (2015). Technological Problem Solving as Skills for Competitive Advantage: An Investigation of Factors Associated with Levels of Pupil Success. In *11th International Conference on Technology Education in the Asia-Pacific Region*. Hong Kong Polytechnic University: Hong Kong.
- Morrison-Love, D. (2017). Towards a Transformative Epistemology of Technology Education. *Journal of Philosophy of Education*, 51(1), 23-37. doi:10.1111/1467-9752.12226
- National Education and Monitoring Project (NEMP). (2008). *2008 Technology Assessment Results*. National Education and Monitoring Report 48.
- National Research Council (NRC). (2009). *Engineering in K–12 Education: Understanding the Status and Improving the Prospects*. Washington, DC: National Academies Press. Retrieved from <https://www.nap.edu/catalog/12635/engineering-in-k-12-education-understanding-the-status-and-improving>
- OECD. (2017). Education at a glance. Retrieved from <http://www.oecd.org/education/educationataglance2017-countrynotes.htm>
- Rich, K. M., Strickland, C., Binkowski, T. A., Moran, C. and Franklin, D. (2017). K-8 Learning Trajectories Derived from Research Literature: Sequence, Repetition, Conditionals. In *Proceedings of the 2017 ACM Conference on International Computing Education Research* (pp. 182-190), Washington, USA: ACM.
- Rich, K. M., Binkowski, T. A., Strickland, C. and Franklin, D. (2018). Decomposition: A K-8 Computational Thinking Learning Trajectory. In *Proceedings of the 2018 ACM Conference on International Computing Education Research* (pp. 124-132). Espoo, Finland: ACM.
- Rich, K. M., Strickland, C., Binkowski, T. A. and Franklin, D. (2019). A K-8 Debugging Learning Trajectory Derived from Research Literature. In *Proceedings of the 50th ACM Technical Symposium on Computer Science Education* (pp. 745-751), Minneapolis, USA: ACM.
- Seiter, L., Foreman, B. (2013). Modelling the Learning Progressions of Computational Thinking of Primary Grade Students. In *Proceedings of the 9th Annual International ACM Conference on International Computing Education Research* (pp. 59-66), San Diego, San California, USA: ACM
- Sorva, J. (2013). Notional Machines and Introductory Programming Education. *ACM Transactions on Computing Education*, 13(2), Article 8. Retrieved from <https://dl.acm.org/citation.cfm?id=2483713>
- Teague, D. (2015). Neo-Piagetian Theory and the Novice Programmer. PhD by Publication, Queensland University of Technology. Retrieved from <https://eprints.qut.edu.au/86690/>

- Rosa, A. & Montero, I. (1990). The Historical Context of Vygotsky's Work: A Sociohistorical Approach. In Moll, L.C. (Ed.) *Vygotsky and Education: Instructional Implications and Applications of Sociocultural Psychology*. New York, NY: Cambridge University Press.
- Welsh Government. (2015). A Curriculum for Wales - A Curriculum for Life. Cardiff: Welsh Government. Retrieved from https://dera.ioe.ac.uk/24680/1/151021-a-curriculum-for-wales-a-curriculum-for-life-en_Redacted.pdf
- Wheater, R., Ager, R., Burge, B. and Sizmur, J. (2013). Achievement of 15-Year-Olds in Wales: PISA 2012 National Report (OECD Programme for International Student Assessment). Slough: NFER. Retrieved from <http://www.nfer.ac.uk/publications/PQUK02>
- Wong, G.K. and Jiang, S. (2018). Computational Thinking Education for Children: Algorithmic Thinking and Debugging. In *2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)* (pp. 328-334). Wollongong, NSW, Australia: IEEE.
- Wyeth, P. (2008). How Young Children Learn to Program with Sensor, Action, and Logic Blocks. *Journal of the Learning Sciences*, 17(4), (pp.517–550). Retrieved from <https://doi.org/10.1080/10508400802395069>
- Wyse, D., Hayward, L. and Pandya, J. (2016). Introduction. In Wyse, D., Hayward, L. and Pandya, J. (Eds.). *The Sage Handbook of Curriculum, Pedagogy and Assessment*. Sage Publications (pp. 1-26). London.

Developing university pedagogy in engineering higher education.

Sonja Niiranen, Johanna Naukkarinen Lappeenranta



Sonja Niiranen
Tampere University
Finland
sonja.niiranen@tuni.fi



Johanna Naukkarinen
Lappeenranta-Lahti University of Technology
Finland
johanna.naukkarinen@lut.fi

ABSTRACT

The pedagogical training in engineering education aims to strengthen the participants' pedagogical expertise through self-reflection and collegial collaboration. In spring of 2019, a course titled 'Planning and assessment for learning in engineering higher education (5cr)' was offered for the first time to all staff members across the new Tampere University and is going to be repeated later the same year at LUT University (Lappeenranta-Lahti University of Technology LUT). This study investigates engineering higher education teachers' approaches to teaching and in particular to assessment. A mixed-method approach was used to examine these approaches in engineering education. First, an electronic survey was distributed to gather information from teaching staff members in the fields of engineering education at the Tampere University and LUT University. Altogether 56 members of teaching staff ($N=56$, 31 females and 25 males) answered the survey. The survey data were analyzed by using frequentist descriptive statistical methods (comparing means and standard deviations). Furthermore, a descriptive analysis was performed with a semi-structured self-evaluation questionnaire for the participants ($N=12$) at the end of their pedagogical training course 'Planning and assessment of student learning in engineering higher education'. Findings of this study suggest that Finnish engineering higher education teachers prefer student-focused approach in teaching. They also seem to hope to receive some theoretical, but rather practical examples and ideas for teaching from their pedagogical training.

Keywords: university pedagogy; engineering education; approaches to teaching; assessment

Introduction

There is a growing need for teachers at the university to provide students flexibility in their studies and move from teacher-oriented approaches to teaching towards student-centred practices. During the past 15 years, Finnish universities have begun to provide pedagogical training that are aimed to improve the teaching practises and skills of university teachers (Postareff, 2007). Teachers should be helped to apply student-centred approaches because they are likely to have positive effect on learning of students (Gibbs & Coffey, 2004). There

has also been an increased concern about the need to develop a better understanding of how people learn engineering (Johri, Olds, & O'Connor, 2013). Teachers are those who are building bridges between the contents and actions during the courses. Thus, the course designer must have the ability to understand the situational and contextual constraints and also analyse practical learning problems i.e. to understand the position of the learner (Ertmer & Newby, 2011). This means that teachers have to consider both, the elements of different learning theories and measurable learning outcomes, and how to provide students possibilities to develop their knowledge and skills further.

It has been argued that situativity should be seen as a dominant perspective in engineering discipline by emphasising the role of the environments that require extensive content knowledge and analytical skills to engage in learning (Johri & Olds, 2011; Pleasants & Olson, 2018). The situative perspective is broad and it can be referred to as situated cognition (Brown, Collins, & Duguid, 1989; Greeno, 1989; O'Connor & Glenberg, 2003), cognition in practice (Lave, 1988), situated learning (Lave & Wenger, 1991), situated action (Suchman, 1987), sociocultural psychology (Rogoff, 1990; Wertsch, 1993), activity theory (Engeström, 1987), and distributed cognition (Hutchins, 1995) (in Johri, Olds & O'Connor, 2013, p. 48). Therefore, it is important that teachers have adequate repertoire of strategies available and possess the knowledge of when and why to employ each (Ertmer & Newby, 2011). Johri, Olds and O'Connor (2013) presents three distinguishing characteristics of situated engineering learning: 1) use of representations, 2) alignment with professional practices, and 3) the emphasis on design. The first element, the use of *representations*, is a typical element in engineering as engineers are surrounded by tools and the purpose of many of these tools is to lead to representations that can help guide the work of engineers. The second critical aspect of engineering and engineering learning is its close association with *professional practice* due to the fact that a majority of engineers pursue the profession to be able to work as engineers. A final element of engineering learning that is *design*. Engineers are by definition designers. When identifying characteristics of engineering (Pleasants & Olson, 2018), most of the features are closely related to engineering design. (Johri, Olds, & O'Connor, 2013.)

Professional development is seen as a continuous process of reflecting on pedagogical approaches in practical teaching and instructional contexts. Teachers who engage in discussions with their fellow teachers and pursue collaboration that cuts across conventional disciplinary boundaries gain new ideas and support for conducting teaching experiments. As the professional knowledge about teaching and learning processes expands, new types of expertise is required of educators at all levels (Postareff, 2007). The purpose of this study was to develop university pedagogy in engineering education. In order to do that, the aim was to explore engineering education teachers' approaches to teaching.

Engineering pedagogy

In the field of engineering, educators are called upon to help learners to develop analytic, communication, and teamwork skills, while meeting ever increasing content demands and cultivating independent learners (Johri & Olds, 2011). The pedagogical training in engineering higher education aims to strengthen the participants' pedagogical expertise through self-reflection and collegial collaboration. The courses foster a research- and development-oriented approach to teaching among the participants by exploring their personal experiences and theoretical perspectives. The aim is to enhance the participants' ability to engage in pedagogical discussions and promote community spirit. The courses cover a range of pedagogical themes that are discussed in the multidisciplinary context of the different fields of engineering. The overarching themes of the courses are the utilisation of ICT tools in education to support interactive learning and teaching, support for student learning and their self-regulation as well as labour market relevance.

Engineering pedagogy is not committed to any single learning theory, as nicely illustrated by Newstetter and Svinicki (2013), who show how instruction is and can be related to behaviourism, cognitivism and situativity. It may well be that the elective use of theories typical for engineering science (Hendricks, Jacobsen and Pedersen, 2000) is also reflected in the engineering teacher's way to 'use whatever seems to work'. Despite, or perhaps due to, the multiple paradigms, it is very important, that educators understand their own views of teaching and learning and can reflect upon their classroom activities and instructional designs against that. Hence it is equally important for the pedagogical teacher trainers to have a general idea of the teaching orientations of their trainees.

In spring of 2019, a course titled 'Planning and assessment for learning in engineering higher education' was offered for the first time to all staff members across the new Tampere University and is planned to be replicated later the same year at the LUT University (Lappeenranta-Lahti University of Technology LUT). The course explores the planning of learning activities and the assessment of student learning in the fields of engineering. During the course, the participants will analyse the current state of one of their own courses and prepare a plan for the development of the course.

Research question and methods

An electronic survey investigating teachers' approaches to teaching was distributed to teaching staff members in the fields of engineering education at the Tampere University and LUT University. Altogether 56 members of teaching staff ($N=56$, 31 females and 25 males) answered to the survey. Participants were between 23-64 years old and reported being working in various departments such as Faculty of Engineering and Natural Sciences, Faculty of Management and Business, Faculty of Built Environment and Faculty of Information Sciences and Communication, School of Energy Systems and School of Engineering Science at the before mentioned universities. The electronic survey contained some demographic questions (age, gender, faculty/department) and 20 statements related to approaches to teaching (Postareff, 2007). Statements (items) related to approaches to teaching were presented with a 5 -point scale (1= only rarely, 5= almost always). The items (1-20) represented different approaches to teaching: 1-8 Student-focused of approach (CCSF), 9-16 Teacher-focused approach (ITTF) and 17-20 Teachers' self-efficacy beliefs (Postareff, 2007). In order to examine the structure of teachers' approaches to teaching the data were analyzed by use frequentist descriptive statistical methods (comparing means and standard deviations). The items 1-16 are presented in Table 1 and items 17-20 within the findings.

Furthermore, a descriptive analysis was performed with a semi-structured self-evaluation questionnaire at the pedagogical training course 'Planning and assessment of student learning in university-level engineering education'. The questionnaire was sent to all the participants ($N=13$) by email after the pedagogical training course and research permit was asked at the end of the questionnaire.

Findings from the approaches to teaching (ATI) questionnaire

In Table 1. the items measuring *student-focused approach* to teaching (CCSF) are marked in bold and the items measuring *teacher-focused approach* to teaching (ITTF) are with normal font. The high means of the four items measuring the CCSF (Q3, Q5, Q8, Q15) indicate that teaching staff members in engineering education prefer student-focused approaches in their teaching. This was also supported by the lowest average values being mostly items measuring ITTF (Q12, Q11, Q7 and Q13). It is notable, that the item Q9, which is not measuring ITTF, but showed low average, might reflect the study culture about debating in engineering education. This can be seen from dispersion of the data (see Table 2).

Table 1. Items as questions (Q1-16) in the survey, means from the highest to the lowest mean and standard deviations. CCSF items bolded and ITTF items normal font.

	Items measuring teachers approaches to teaching	<i>M</i>	<i>SD</i>
Q3	In my interaction with students I try to develop a conversation with them about the topics we are studying.	4.35	.844
Q5	I feel that assessment should be an opportunity for students to reveal their changed conceptual understanding of the subject matter.	4.16	.898
Q8	I encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop.	4.04	.816
Q15	I feel that it is better for students to generate their own notes rather than copy mine.	3.87	1.080
Q10	I create structures to help students to pass the formal assessment items (exams, reports, presentations etc.).	3.77	.934
Q14	I make available opportunities for students to discuss their changing understanding of the subject matter.	3.57	1.024
Q2	I feel it is important that courses should be completely described in terms of specific objectives relating to what students have to know for formal assessment items.	3.54	1.023
Q1	I design my teaching with the assumption that most of the students have very little knowledge of the topics to be covered.	3.38	.964
Q4	I feel it is important to present a lot of facts to students so that they know what they have to learn for.	3.09	1.005
Q6	I set aside some teaching time so that students can discuss, among themselves, the difficulties that they encounter studying this course.	2.78	1.212
Q16	I feel a lot of teaching time should be used to question students' ideas.	2.73	.981
Q7	I concentrate on covering the information that might be available from a good textbook.	2.56	1.058
Q13	I feel that I should know the answers to any questions that students may put to me.	2.57	1.291
Q11	I think an important reason in teaching is to give students a good set of notes.	2.54	1.128
Q9	In teaching, I use difficult or undefined examples to provoke debate.	2.49	1.275
Q12	I only provide the students with the information they will need to pass the formal assessment.	1.64	.645

The overall average of all respondents for CCSF orientation was 3.50 and for ITTF 2.89. Nevgi et al. (2009) conducted a study in another Finnish university and in their data the respective averages for teachers from hard applied sciences were 3.62 and 3.34. However, their study did not include any engineering teachers.

The survey also focused on exploring engineering education teachers' self-efficacy beliefs with teaching (questions 17-20 in the survey).

Q17: I am confident that my knowledge of the subject matter is not a barrier to teaching it well.

Q18: I am confident that students will learn from me in my courses.

Q19: I am certain that I have the necessary skills to teach.

Q20: I am confident that my knowledge of teaching is not a barrier to teaching well.

Investigation of average values showed that overall teachers' beliefs are high due to high means (all over 3.95). Teachers were confident that their knowledge of the subject matter and teaching is good. They were also confident that students will learn from them in their courses and that they have the necessary skills to teach.

Findings from the self-evaluation questionnaire

Participants (N=12) were asked to reflect on various statements in relation to their pedagogical training course objectives in scale 1=No change, 2=Only a little, 3=Somewhat, 4=Quite a lot, 5= A lot. In the following we'll present some of the questions and participants' reflections (N=11) in more detail.

The highest mean was with the statement "I'm interested in trying out new student-oriented evaluation methods" (M=4,09).

- *'The course gave me the tools I could use in evaluation. The development plan raised the current course situation and gave motivation to improve the course.'*
- *'Case examples were interesting and gave a good idea of how the evaluation can be implemented in practice.'*
- *'I learned to look at evaluation as a concrete part of teaching.'*
- *'Practical tips for self and peer review. The purpose of peer review is to encourage others to learn.'*

Participants evaluated that their pedagogical thinking and understanding about the approaches to evaluation evolved over the course (M=3,73).

- *'Above all, the assessment guides students' learning processes and it is important to align it with the objectives and contents of the course.'*
- *'I realized that many of the teaching methods that I had been using for a long time are in fact more assessment of learning than teaching (assessment for learning).'*
- *'Flipped learning. The importance of formative assessment and internal motivation.'*
- *'Studying student's competences and developing the student's meta-cognitive self-assessment will be part of my teaching in the future.'*
- *'Evaluation is more about guiding learning than giving values.'*
- *'I learned that evaluation is a broader concept than just grading and can also be used to support learning.'*

Discussion

There are many driving forces that require engineering educators to develop engineering programs (Felder, Brent, & Prince, 2013). Thus, continuing professional development and possibilities for teaching staff members to focus on improving teaching should be seen as a crucial component of faculty development programs. Postareff (2007) points out that pedagogical training has an effect on teaching in higher education by enhancing the adoption of the conceptual change/student-focused approach to teaching. She also adds that university pedagogical training is a significant way to help teachers to develop more student-focused ways of teaching (Postareff, 2007).

The findings of this study imply that Finnish engineering higher education teachers prefer student-focused approach in teaching. This contradicts some previous findings, where engineering teachers have been noted to have stronger ITTF orientation to teaching (Lueddeke, 2003). Engineering is often referred as a “hard discipline”. Nevgi et al. (2009) discovered that teachers from hard disciplines are more clearly either student or content focused and that both orientations are equally strongly represented among the teachers, whereas teachers from the soft disciplines have stronger student than content orientation to teaching. Nevertheless, our results suggest about the same degree of student-focused approach and a lower level of content/teacher focused approach than their teachers from hard applied disciplines, which did not include engineering.

It is interesting to note, that the ATI instrument relies quite heavily on different types of discussions as a sign of student-centredness and activation. In engineering much of the disciplinary knowledge is embedded in different artefacts and much of the learning happens by doing and constructing things. With many engineering topics, the student-centredness may not be so much about having the students to create their own knowledge by discussing than about giving them opportunities to really exercise pieces of engineering work and relate through that to different aspects of situated learning. Thus, it could well be that the engineering teachers are more student-oriented than previously thought, but that the instruments we use to measure the orientations do not appropriately take into account the nature of engineering knowledge and learning processes. This is further supported by the strongly student-oriented views towards assessment practises expressed in our second self-evaluation questionnaire.

A limitation of this study is that the number of responses was rather low if we think of all those who are in teaching related position in engineering higher education in these two universities. In the future, collecting a bigger and more representative data to corroborate our findings will be needed. Also, it would be interesting to ask teachers to answer to the ATI questionnaire before and after pedagogical trainings to see what kind of effects the trainings may produce and in which time frame they might occur. Further, investigating the engineering educators' views on learning and their connections to the teaching orientations, as well as the correlations between teaching beliefs and teaching intentions (e.g. Norton et al., 2005) would provide valuable insights for the development of teacher trainings in engineering pedagogy.

Summary

This study investigates engineering higher education teachers' approaches to teaching and in particular to assessment. A mixed-method approach was used to examine these approaches in engineering education. Findings suggest that Finnish engineering education teachers prefer student-focused approach in teaching. They also seem to hope to receive some theoretical, but rather practical examples and ideas for teaching from their pedagogical training.

References:

- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18, 32–42.
- Engeström, Y. (1987). Learning by expanding: An activity-theoretical approach to developmental research. Helsinki: Orienta-Konsultit Oy.
- Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, 26(2), 43–71.
- Felder, R. M., Brent, R., & Prince, M. J. (2013). Engineering instructional development. Programs, best practices, and recommendations. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 409–436). New York, NY: Cambridge University Press.
- Gibbs, G., & Coffey, M. (2004). The impact of training of university teachers on their teaching skills, their approaches to teaching and approaches to learning of their students. *Active learning in Higher Education*, 5, 87–100.
- Greeno, J. G. (1989). A perspective on thinking. *American Psychologist*, 44(2), 134–141.
- Hendricks, V. F., Jakobsen, A., & Pedersen, S. A. (2000). Identification of Matrices in Science and Engineering. *Journal for General Philosophy of Science*, 31(2), 277–305.
- Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.
- Johri, A., & Olds, B. M. (2011). Situated engineering learning: Bridging engineering education research and the learning sciences. *Journal of Engineering Education*, 100(1), 151–185.
- Johri, A., Olds, B. M., & O'Connor, K. (2013). Situative frameworks for engineering learning research. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 47–66). New York, NY: Cambridge University Press.
- Lave, J. (1988). *Cognition in practice*. Cambridge UK: Cambridge University Press.
- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.
- Lueddekke, G.R. (2003). Professionalising Teaching Practice in Higher Education: a study of disciplinary variation and 'teaching-scholarship'. *Studies in Higher Education*, 28(2), 213–228.
- Nevgi, A., Lindblom-Ylänne, S., & Levander, L. M. (2009). Tieteenalakohtaiset erot opetuksellisissa lähestymistavoissa [Disciplinary differences in approaches to teaching]. *Peda-Forum*, 2, 6–15.
- Newstetter, W. C., & Svinicki, M. D. (2014). Learning Theories for Engineering Education Practice. In A. Johri & B. M. Olds (Eds.), *The Cambridge Handbook of Engineering Education Research* (pp. 29–46). Cambridge University Press.

Norton, L., Richardson, J.T.E., Hartley, J., Newsteadt, S., Mayes, J. (2005). Teachers' beliefs and intentions concerning teaching in higher education. *Higher Education*, 50, 537–571.

O'Connor, K., & Glenberg, A. M. (2003). Situated cognition. In L. Nadel (Ed.), *Encyclopedia of cognitive science*. London: Nature Publishing Group.

Pleasant, J., & Olson, J.K. (2019). What is engineering? Elaborating the nature of engineering for K-12 education. *Science Education*, 103, 145-166.

Postareff, L. (2007). Teaching in higher education. From content-focused to learning-focused approaches to teaching. University of Helsinki. Department of Education – Research Report 214.

Rogoff, B. (1990). Apprenticeship in thinking: Cognitive development in social context. New York, NY: Oxford University Press.

Suchman, L. (1987). *Plans and situated action*. New York, NY: Cambridge University Press.

Wertsch, J. V. (1993). *Voices of the mind*. Cambridge, MA: Harvard University Press.

How teachers value skills and content in Technology teaching in Swedish compulsory school – a “climate” change.

Charlotta Nordlöf, Susanne Engström



Charlotta Nordlöf
Linköping University
Sweden
charlotta.nordlof@liu.se



Susanne Engström
Royal Institute of Technology
Sweden
sengstro@kth.se

ABSTRACT

In the Swedish curricula, Technology is described in terms of five skills and core content divided into three areas. In this paper, we interpret and define the three areas of core content, founded on different scientific base areas (SBA): (1) Engineering science, (2) Developing and making and (3) Human, society and environment.

The SBA-model is based on the Swedish Technology curriculum and is constructed with inspiration from previous research in natural science education (Östman, 1995); with relation to the philosophy of technology knowledge (e.g., Ropohl, 1997) and to technology education; in curriculum emphasis (Klasander, 2010), in different views of technology among students (DiGironimo, 2011).

Technology has developed from being a vocational subject to a broader, complex and comprehensive subject. Evaluations show that teachers in Sweden have difficulties in interpreting the content of the whole subject and its skills. During the autumn and winter 2018-2019, CETIS developed a material for inspiration of teachers, which shows the width of the subject including skills, content and time consumption. In the present study, we showed the material to about 130 teachers. We asked them to discuss it in groups and to fill in a form. In the form, they were asked to value the five skills of technology, based on how important they rate the skills in comparison to each other. They could also express their opinions of the material. We analysed their values of the skills and their opinions about content in relation to SBA. The result shows that the teachers focus on SBA 2 Developing and making and SBA 3 Human, society and environment when they teach Technology. Compared to previous studies, the focus in teaching is transferred towards social and environmental aspects.

Keywords: technology teachers, technology education, subject content, technology knowledge, skills in technology

Introduction

In Sweden the subject of technology has developed from being a vocational subject to a subject of wider range (Bjurulf, 2008). Technology became a mandatory subject in Swedish compulsory schools in the early 1980's. Today it is a complex, comprehensive and multidisciplinary subject (Swedish National Agency for Education, 2018).

In the Swedish curriculum (Swedish National Agency for Education, 2018) the subject of Technology is described in terms of five skills:

Teaching in technology should essentially give pupils the opportunities to develop their ability to:

- (F1) identify and analyse technological solutions based on their appropriateness and function.
- (F2) identify problems and needs that can be solved by means of technology, and work out proposals for solutions,
- (F3) use the concepts and expressions of technology,
- (F4) assess the consequences of different technological choices for the individual, society and the environment, and
- (F5) analyse the driving forces of technological development and how technology has changed over time. (Swedish National Agency for Education, 2018, p. 296)

Further, the curriculum includes an amount of core content, which are divided in three areas named (cc1) *Technological solutions*, (cc2) *Working methods for developing technological solutions* and (cc3) *Technology, man, society and the environment*.

Evaluations show that Swedish teachers have difficulties in interpreting the content of the whole subject and the skills. Teachers prioritising the second skill F2, *identify problems and needs that can be solved by means of technology, and work out proposals for solutions* and the specific core content (cc2) *Working methods for developing technological solutions*, and letting the practical parts of technology teaching dominate (Swedish Schools Inspectorate, 2014; Fahrman et al., 2019).

In another study, carried out during 2013-2014 and presented at PATT 29 (2015), 223 Swedish Technology teachers answered a questionnaire about technology teaching. The participating teachers taught in grade 7-9, and they were invited to express *what technology is*, within the school context and further answer the question *what is the main purpose of the technology teaching?* The result shows a view of technology that encompasses artefacts but also how artefacts and technical systems are put into a larger social context with valuable purposes for mankind and other benefits. Most teachers believe that the most important purpose of technology education is to put the technology into broader contexts and to learn how to act within the everyday life. The design and make phase are also expressed by the teachers as an important purpose. Few teachers indicate purposes that can be compared to industrial processes or sustainable development aspects (Engström & Häger, 2015).

There seems to be a connection between what the teachers choose to focus in Technology teaching and their explicit purpose of the subject (Fahrman et al., 2019). In science education, studies have shown that there is a connection between the aim of a subject, the teacher's choice of content and skills, and the scientific base of the subject content (Roberts, 2007; Ryder & Banner, 2013; Lidar et al., 2018). We intend to examine this in technology education.

Aim

The aim of this paper is to obtain a deeper understanding of how teachers in Sweden view the content and the aim of the subject. By comparing the teachers answers to the framework for the scientific base of the subject content of Technology, we will analyse the teachers' views of the subject content.

The research questions are:

- What skills in the Swedish technology subject are most important, according to the teachers and the teacher educators?
- Is there a scientific base of the technology subject content that is more central than the others, according to the teachers and the teacher educators?

First, the shape of the theoretical framework and how it is built will be described, and further, how it can relate to teachers teaching and their aim of the teaching.

Theoretical framework

In the field of natural science education, Roberts (2007) found seven curriculum emphasis. Those have been adapted in Swedish research (e.g., Östman, 1995). Roberts means that a teacher doesn't teach a science topic in vacuum. The curriculum emphases can be described as curriculum context. According to Östman, a teacher can't only choose concepts and theories – these must be placed in a context, a curriculum emphasis. A subject area can be in the context of two or more curriculum emphasis, but the result will be very different, depending on the emphasis. In technology education it could be the same. Depending on what context the teacher sets up, the teaching will be different.

By reading, studying and interpreting the curriculum, we can see a framework for the scientific base of the subject content of Technology emerging. The framework can be described within three parts, representing three areas of the scientific base of the subject content of Technology. With inspirations from the three areas in the Technology curriculum, the scientific base areas (SBA) are named (1) *Engineering science*, (2) *Developing and making*, and (3) *Human, society and environment*.

In previous research, attempts have been made to divide knowledge, technology and the technology subject in categories or types. In the following section we will list some examples. Firstly, a short description in text is made, secondly, the framework in Table 1 is built by structuring the different theoretical references divided in the three SBA. Previous adjoining studies can relate to the three SBA in the framework, and thereby create a wider and deeper base for understanding the core of the subject.

There are three kinds of knowledge, that origins from the ancient Greece. Episteme is the true knowledge of the world, sometimes named theoretical scientific knowledge (Gustavsson, 2000), Techne is the knowledge in making, manufacturing and craft, sometimes called practical productive knowledge (Gustavsson, 2000) and Phronesis is another kind of practical knowledge that concerns the human world (Gislén et al., 2006). Gislén et al., suggest a translation of Phronesis to *street smart* when using modern language. Gustavsson (2000) describes Phronesis in the modern world as an attitude to the possibilities in the society, asking questions about ethics and politics, and with the human in focus. The three SBA are far away from absolute connected to the three kinds of knowledge, but still we see inspiration mainly from Episteme, Techne and Phronesis in each area.

Philosophers within technology have presented different models and frameworks (e.g., Ropohl, 1997, DeVries, 2003 and Hansson, 2013). One example is Hansson (2013), dividing

technological knowledge in *tacit knowledge*, *practical rule knowledge*, *technological science* and *applied science*, ordered from practical knowledge to theoretical knowledge. A second example is Ropohl's (1997) knowledge types in technology: *Technical know-how*, *Functional rules*, *Structural rules*, *Technological laws* and *Socio-technological understanding*. Still, there is no unified view of technological knowledge. Further, Dakers (2006) provides his views of the technological world in the introduction of the book about *technological literacy*. He begins with a description of technology in general. Young people tend to see technology as artefacts, and Dakers explains the importance to both use and relate to a technological world. Technology can also be the processes and knowledge that creates the artefacts and further, how the technology affects society.

While Dakers (2006) discusses technological literacy, Klasander (2010) focuses on different aims of technology education - teaching traditions in technological systems. Klasander describes Technology teaching in six curricula emphasises. The intentions of the emphasises are to explain why the teaching has this or that focus, and they reveal the underlying aims of the teaching. In Table 1 the six emphasises are connected to the SBA, an interpretation by the authors of this paper, pointing to how the scientific base of the content can be typically associated to Klasander's emphasises. DiGironimo (2011) investigates students' perceptions about the nature of Technology and describes Technology as a three-sided prism with a top and bottom. The three sides represent the shape and structure of technology, and they can be typically associated to the three SBA of technology subject content as shown in Table 1. The top and the bottom represent the historical perspectives of technology, with the bottom as the past and the top as the role of technology in society today.

The examples of different views of technology, of technological systems, the nature of technology and technological literacy shows how researches have viewed technology from their perspectives, with an intention to divide it in different parts or areas within the school context. From these perspectives the picture of the SBA of technology subject knowledge can have its take-off. By bringing these different perspectives and descriptions together and by focusing on the subject content of technology, a framework is appearing.

Finally, the skills in the curriculum are analysed and connected to the framework. Skills 3 and 5 are not included in the framework, since they both cover skills that are ongoing all the time in technology teaching, and don't represent a special scientific base.

In SBA 1, *Engineering science* the scientific base of the subject content, mainly arise from engineering science and natural science, including knowledge that is mainly theoretic, like Technological science and applied science (Hansson, 2013). In SBA 2, *Developing and making*, proven experience is the base. This is practical knowledge, e.g. like tacit knowledge and practical rule knowledge (Hansson, 2013). The third SBA, *Human, society and the environment*, is based on other sciences and ideologies.

The three SBA can be analogous to three pillars that build the Technology subject. All three of them are needed, according to the curricula. The three pillars aren't necessarily needed to equal extent. In Technology, a teacher can teach about, for example, bridges. The teaching will be different depending on which SBA for the content the teacher has focus on. You can teach about bridges focusing on materials and their properties (SBA 1), you can focus on experiments with models of bridges (SBA 2) or you can focus on the values of bridges, why we build them, what consequences they have for society and so on (SBA 3). To work with a theme with content related to all three SBA provides the desired width of the subject.

Table 1. An overview of the theoretical framework, the scientific base area (SBA) of the school subject content in Technology and related perspectives.

Reference, source, related aspects and theoretical perspectives	SBA 1 Engineering science	SBA 2 Developing and making	SBA 3 Human, society and the environment
A description of the origin of the knowledge content	The knowledge content originates from engineering science in combination with natural science. (e.g., Hansson, 2011)	The knowledge originates from proven experience (e.g., Hansson, 2011).	The technology knowledge content has relations to other sciences. For example, sociological, ecological, ethical, political and environmental aspects. Also, action knowledge (DeVries, 2003) and socio-technological understanding (Ropohl, 1997). Dealing with actions the human world (Gislén et al., 2006).
The philosophical form of knowledge (Gislén et al., 2006; Gustavsson, 2000).	Episteme	Techne	Phronesis, but also Episteme
Core content in curriculum	(cc1) Technological solutions	(cc2) Working methods for developing technological solutions	(cc3) Technology, man, society and the environment.
Skills in curriculum	f1, (f2) identify and analyse technological solutions based on their appropriateness and function.	f2 identify problems and needs that can be solved by means of technology and work out proposals for solutions.	f4 assess the consequences of different technological choices for the individual, society and the environment.
Klasander (2010); teachers different aims of technology education, and thereby emphasise content	The industrial emphasis (Ind), The coping with your everyday life emphasis (EvD), The techno-historical emphasis (THi)	The design-and-make emphasis (D&M), The industrial emphasis (Ind)	The sustainable development emphasis (SD), The coping with your everyday life emphasis (EvD), The democratic citizen emphasis (DemC), The techno-historical emphasis (THi)
DiGironimo (2011);	Technology as	Technology as a	Technology as human

students' different definitions of technology, and thereby a relation between definition and content will emerge	artefacts (d1) History of Technology (d4)	creation process (d2)	practice (d3), History of Technology (d4), The Current Role of Technology in Society (d5)
--	--	-----------------------	---

Methods

In 2018, a material for inspiration in technology teaching has been developed by CETIS (Centre for School Technology Education), The material is based on the Swedish curriculum and shows the width and the depth of the subject. Its aim is to focus on all skills of the subject and cover all core content. In six occasions in 2018-2019, the material was presented to a total of 130 teachers for grades 1-9, and 12 teacher educators.

After the presentation the participants had an opportunity to look closer to the material and discuss it in groups. In the end of the session they were asked to individually fill in a form and rank the skills of the Technology subject in comparison to each other.

By starting with a presentation of the core content and the skills in Technology, a context where all the participating teachers and teacher educators had seen the same examples of core content and skills was set up. Hence, all of them had the same outset when answering the questionnaire. By doing so, they were forced to answer the questions in their own points of view of the subject, in relation to the unified outset.

Before analysing the empirical material, each respondents' ranking of the five skills (F1-F5) were transformed into a ranking of the three skills significant in the framework (F1, F2 and F4), and thereby took in consideration, only those three.

Further, there was an opportunity to answer additional questions by e-mail. 29 teachers did thereby answer two additional questions: (1) *What technology knowledge do you find important for the students to meet and develop in technology teaching in compulsory school?* (2) *Is there any knowledge content in the technology teaching or in the technology curriculum that you find redundantly?*

Both the result from ranking of the skills, and a thematic analysis of the free-text answers are related to the framework (Table 1).

Results

The empirical material used in this study consists of 130 teachers' ranking of three skills, with relevance within technology teaching. And, also, free-text answers to two questions, from 29 teachers.

Nearly all teachers (n=125) carried out the ranking. This act is a result in itself. It says something about the participants, they are not inconvenient with valuing the skills and they don't dispute being asked to do so. The result of the ranking is presented in Figure 1. Most teachers rank skill F4 as number one.

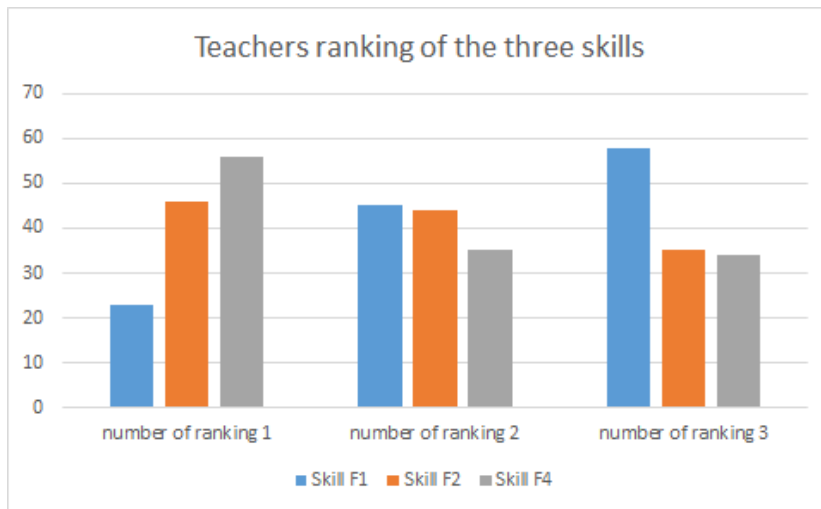


Figure 1. Ranking results.

There is a relation between the skills and the scientific base of the core content (in this study called SBA). Skill F1 is related to SBA 1, F2 to SBA 2 and F4 to SBA 3. Skill F4 and F2 are ranked higher than skill F1, thereby SBA 3 and 2 are valued higher than SBA 1.

When analysing the free-text answers from 29 respondents several views were found. The answers to the first question, “What technology knowledge do you find most important for the students to meet and develop in technology teaching in compulsory school?”, is presented in Table 2. The table presents how and to what extent the outcomes of answers relates to SBA.

The second free-text question was “Is there any knowledge content in the technology teaching /technology syllabus that you find needless?”. 11 of the respondents didn’t answer the question at all. 10 respondents answered that there was no knowledge content that they found needless. The teachers that gave examples of what they found needless only gave examples that corresponded to SBA 1 and 3. No teachers gave examples of content knowledge that correspond to SBA 2. Three teachers gave examples that corresponded to SBA 3, two teachers gave examples that corresponded to SBA 1, and two gave examples of content knowledge that corresponded to both SBA 1 and SBA 3.

Table 2. Number of respondents that describe what kind of technology knowledge that is most important within their teaching, and how the answers relate to the three SBA (scientific base areas) or not. (X) = relation, (-) = no relation.

Number of respondents	SBA 1 Engineering science	SBA 2 Developing and making	SBA 3 Human, society and the environment	Outcomes of answers with citations as examples Answers to the question <i>What technology knowledge do you find most important for the students to meet and develop in technology teaching in compulsory school?</i>
8	-	-	X	T9: It is important that the students get knowledge about the consequences of technology choices. The aspect of environment is important, and so is the aspect of health. It is important to gain knowledge about what improves the life for humans, all over the world.
6	-	-	-	T8: To gain understanding about technology at all. That Technology is fun.
4	X	-	X	T18: Technology will help children to understand the structure and the society. Everyone must not become entrepreneurs, therefore, to understand systems seems more important than to develop your own systems.
3	-	X	-	T22: To work hands-on with technology and not just read.
3	-	X	X	T23: To reflect about choices of technological solutions in relation to a sustainable society. To learn the consequences of technological solutions. To develop your entrepreneurship and the joy of invention.
2	X	X	-	T28: To identify and to construct technological solutions.
2	X	X	X	T1: Programming, documentation, construction, sustainable thinking. Technological solutions and the machines that the students meet in their everyday life.
1	X	-	-	T17: Technology in the everyday life. Technology then and now. Understanding of how technological things are constructed and how they work. Technology in buildings.

Teacher-educators (n=11) ranking of the three skills shows a upon a focus on highlighting mainly the skill F2 but also F4, result presented in Figure 2.

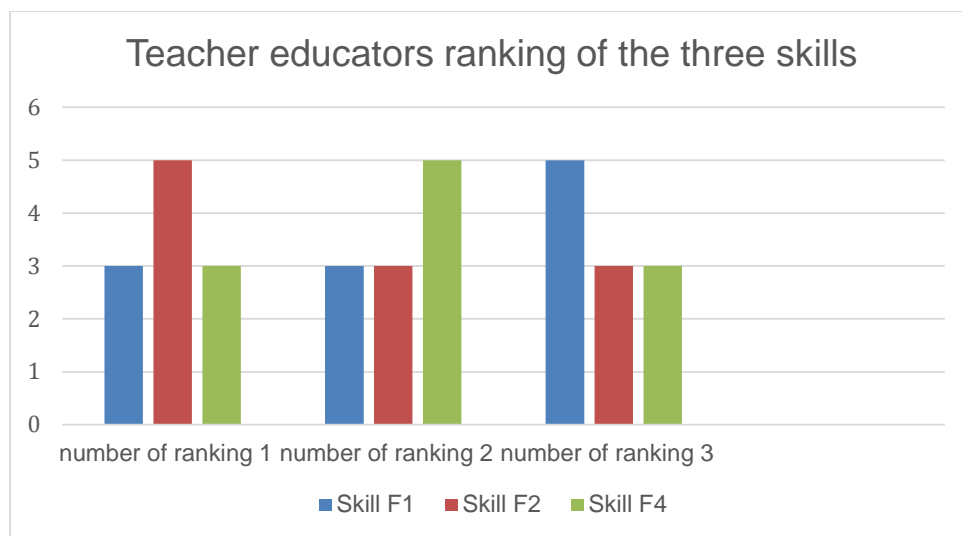


Figure 2. Teacher educators ranking of the skills.

Discussion

As we emphasise in the text above, the content and the skills promoted in the Swedish technology subject cover a complexity and a broadness. The scientific base of the Technology subject content within compulsory school in Sweden could be seen epistemological built upon the three SBA, each one representing a scientific view. The inspiration material for teachers covers all the three SBA and was used as a common base for showing the width of the subject and give a possibility to cover the five skills in the teaching. After reflecting over the inspiration material, the teachers still seem to be comfortable with giving different weight to different skills. In sum, teachers value content with a SBA3 highest, and content with a SBA1 lowest.

This result indicates a change, in comparison to previous studies (Fahrman et al., 2019; Engström & Häger, 2015). From high values of mainly skill F2 and content in relation to SBA 2 (Fahrman et al., 2019), teachers also value skill F4 and content i relation to SBA 3 high, the relationship between technology, humans and the environment. Like Lidar et al. (2018), technology teachers have changed their aims and choices of content more related to SBA 3 (F4, technology, man, society and environment). The global problems with climate change emerging during the last year, can be a reason for this turn in Technology teaching.

In the free-text answers, teachers express how they find content in relation to SBA3 most important for the students to develop in technology. This change from developing and making activities to activities related to human, society and environment could also express that it seems to be common to focus on one content area at the time. Subject content with a scientific base related to engineering science, SBA 1, is valued lowest, by the teachers. From the results in this study, it would be interesting to further investigate if teachers choose to focus on one skill, or one SBA in the model, at the time. Further, this shows how swaying and variably the subject of Technology can be.

It is interesting to compare the technology teachers' and teacher educators' ranking of the skills. There is a difference in the teacher educators' answers, they don't value skill F4 highest

like the teachers do, instead skill F2 is highest valued. Still, both groups value skill F2 relatively high and the teacher education per se could be a ground for developing the view of the subject and be an explanation for why teachers give different skills and related subject content different value.

When investigating a question, you usually ask about what is good or positive. A broader picture may appear by adding a question about what is unnecessary. The answers to the second free-text questions only relates to needless knowledge content in relation to SBA 1 and 3, none of the answering teachers believes that there is needless knowledge content in relation to SBA2. That may indicate that the teachers find content related to SBA 2 to be good as it is.

References

- Bjurulf, V. (2008). *Teknikämnets gestaltningar: en studie av lärares arbete med skolämnet teknik*. Estetisk-filosofiska fakulteten, Pedagogiskt arbete, Karlstads universitet.
- Dakers, J. R. (2006). *Defining technological literacy: towards an epistemological framework*. New York, Palgrave Macmillan.
- De Vries, M. J. (2003). The nature of technological knowledge: Extending empirically informed studies into what engineers know. *Techne: Research in philosophy and technology*, 6(3), 117-130.
- DiGironimo, N. (2011). What is technology? Investigating student conceptions about the nature of technology. *International Journal of Science Education* 33(10): 1337-1352.
- Engström, S., & Häger, J. (2015). Four teacher profiles within technology teaching. In *29th PATT conference (Pupils Attitudes Towards Technology). Plurality and complementarity of approaches in design & technology education, Marseille, France*.
- Fahrman, B., Norström, P., Gumaelius, L., & Skogh, I. B. (2019). Experienced technology teachers' teaching practices. *International Journal of Technology and Design Education*, 1-24.
- Gislén, Y. (2006). Kunskapens villkor. *Fronesis*, 8.
- Gustavsson, B. (2000). *Kunskapsfilosofi: tre kunskapsformer i historisk belysning*. Stockholm: Wahlström & Widstrand, 2000
- Hansson, S. O. (2011). Vad är teknisk kunskap? [What is technological knowledge?]. In *Teknikutbildning för framtiden [Technology education for the future]*, 178-188. Liber, Stockholm.
- Hansson, S. O. (2013). What is Technological Knowledge? In *Technology teachers as researchers* pp. 17-31. Sense Publishers, Rotterdam.
- Klasander, C. (2010). *Talet om tekniska system: förväntningar, traditioner och skolverkligheter*. Norrköping, Linköpings universitet.
- Lidar, M., Karlberg, M., Almqvist, J., Östman, L., & Lundqvist, E. (2018). Teaching traditions in science teachers' practices and the introduction of national testing. *Scandinavian Journal of Educational Research*, 62(5), 754-768.
- Roberts, D. A. (2007): Scientific literacy/science literacy. In Sandra K. Abell & Norman G. Lederman red: *Handbook of Research on Science Education*, 729-780. Mahwah, NJ: Lawrence Erlbaum.

Ropohl, G. (1997). Knowledge types in technology. In *Shaping Concepts of Technology* (pp. 65-72). Springer, Dordrecht.

Ryder, J., & Banner, I. (2013). School teachers' experiences of science curriculum reform. *International Journal of Science Education*, 35, 490–514.

Swedish National Agency for Education. (2018). Curriculum for the compulsory school, preschool class and school-age educare 2011: revised 2018. Stockholm: Skolverket

Swedish Schools Inspectorate (2014). Teknik - gör det osynliga synligt. Om kvaliteten i grundskolans teknikundervisning. Skolinspektionens rapport 2014:04. Stockholm.

Östman, L. (1995). *Socialisation och mening: No-utbildning som politiskt och miljömoraliskt problem*. Uppsala Studies in Education, 61. Stockholm: Almqvist & Wiksell.

Models and modelling in technology textbooks.

Per Norström



Per Norström
KTH Royal Institute of Technology
Sweden
perno@kth.se

ABSTRACT

Engineering models are of many different kinds: drawings, physical models, simulations, mathematical expressions, etc. The roles these models play in introductory technology education has not been thoroughly studied, but they do lead to some pedagogical challenges in the form of transfer problems: Pupils study models (simplified representations) of power plants and combustion engines but are expected to learn about the real phenomena. Swedish technology textbooks for lower secondary school describe pupils' model creation, while neither the nature of models and the modelling process, nor the simplifications in the books' descriptive models are discussed.

Keywords: model, modelling, textbook, technology education

Introduction

The creation and use of various types of models are among the cornerstones of most engineering disciplines. The models vary, from architects' miniature houses, to the mechanical engineers' drawings, and the symbolic models of molecules used in biochemical engineering. To learn how to create, use, evaluate, and revise models are therefore important learning outcomes of engineering and technology education (Justi & Gilbert, 2002; Müller, 2009). This includes the actual process of modelling, as well as how to pick the right model for a certain purpose and interpret results from its use while taking uncertainties and limitations into account.

The purpose of this article is to discuss modelling and model use in elementary technology and engineering education. Examples are picked from the mandatory technology subject in Swedish lower secondary school (years 7–9, pupils are 13–16 years old), its syllabus and textbooks.

Models

The term model has different meanings in different contexts. In this article, it is used in a limited sense, derived from the fields of epistemology, theory of science and philosophy of technology. Currently there is no generally accepted definition within those fields. Most attempted definitions do however have a common core:

A model is a simplified representation of a phenomenon.

This is a very far-reaching description, which includes (but is not limited to) three-dimensional physical models, mathematical representations, drawings, computer simulations, and block charts. In this paper, the main objects of study are models included in printed textbooks. This limits the possible types to static, two-dimensional figures, with explanatory text and mathematical expressions.

Modelling

The creation of a model is hereafter referred to as modelling. Gerlee & Lundh (2012) describes this as a two-step procedure: *isolation* and *simplification*. *Isolation* consists of choosing which of the phenomenon's characteristics that should be included in the model and which to omit (in a car crash simulation model, the driver's body weight could be an important parameter, but his/her hair colour is not). The *simplification* process is about making the model simple enough to be usable. Methods used include idealisation (all solids are homogenous, friction is omitted, gasses are ideal, ...) and so-called black boxing. The latter means that the inner workings of components or sub-systems are not studied, just their inputs and outputs.

In addition to these steps, *presentation* is also important. The same information can be presented graphically, numerically or textually, for example. In the teaching context, a suitable form of presentation is important for the model to fulfil its purpose.

Model use

Hughes (1997) describes a general procedure for model use in the sciences. It is divided into three phases: *denotation*, *demonstration*, and *interpretation* (DDI). *Denotation* concerns identifying the model with the phenomenon (identifying a line in a circuit diagram with a particular wire; this parameter represents the material's inherent resistance to bending; etc.). *Demonstration* is using, manipulating, and getting results from the model (calculating the current through the line/wire on the circuit diagram). *Interpretation* concerns using what was learnt through the demonstration to describe, explain or predict certain aspects of the phenomenon or its behaviour. The model is a simplification, which must be considered during the interpretation.

Models in the technology curriculum

In the Swedish syllabus for technology in compulsory school (Skolverket, 2018), the creation and use of models is included both explicitly and implicitly. 'Physical and digital models' are mentioned in the core contents for years 4–6 and 7–9 as 'working methods for developing technological solutions.' This is also true for sketches and technical drawings (Skolverket, 2018, pp. 297–298). In the knowledge requirements (grading criteria), physical and digital models are mentioned in connection to technological development processes. Only pupils' use of models for documentation is mentioned, not use as analytical tools during the product development process (Skolverket, 2018, pp. 300–302).

Finding the implicit inclusions of models and modelling in the technology syllabus demands a certain amount of analysis and interpretation. The syllabus' introduction states that pupils should develop an 'ability to assess technical solutions' (Skolverket, 2018, p. 296). In many cases this demands an understanding of models, as assessment of a suggested solution is commonly done in an early stage of a development process. Furthermore, the teaching should 'contribute to pupils' understanding of how technology has developed in interaction with other sciences' (Skolverket, 2018, p. 296). To be able to do this, a rudimentary understanding of models is necessary, as the natural sciences are largely model-based endeavours.

The Swedish technology curriculum is based around five central abilities. Models or modelling could be included in at least three of them (Skolverket, 2018, p. 296), but is not mentioned explicitly:

'identify and analyse technological solutions based on their appropriateness and function'
If a pupil is to analyse a diesel engine, a nuclear power plant, or an anti-personnel mine, it is in most cases better (safer, cheaper) to study a model than to study said object.

'identify problems and means that can be solved by means of technology, and work out proposals for solutions'
The proposals of solutions are commonly presented in the form of technical drawings and/or prototypes (i.e. models) that are also used during the 'work out proposals' phase.

'use the concepts and expressions of technology'
Models are central concepts and common expressions of technology.

Similar statements concerning model creation and use exist in other countries' syllabi. In New Zealand, pupils should 'learn how functional modelling is used to evaluate design ideas and how prototyping is used to evaluate the fitness for purpose of systems and products' (Ministry of Education [in New Zealand], p. 2). English pupils should be taught to 'develop and communicate design ideas using annotated sketches, detailed plans, 3-D and mathematical modelling' (Department for Education [in England], p. 2). In the National Science Foundation's (2010) standards for K–12 engineering education, modelling is included in a list of important engineering ideas, and we learn that 'engineers use modeling [*sic*, American] to understand how a product or component may function when in use.' (p. 7). Models and modelling are identified as important content in technology and engineering for primary and secondary school internationally. Different countries focus on different aspects (e.g. communication in England vs. evaluation in New Zealand), but many problems and opportunities are most likely similar.

The textbooks and their use of models

As of March 2019, only four comprehensive technology textbooks for years 7–9 in Swedish compulsory school exist: Fridh (2017), Karlsson & Brink (2017), Sjöberg (2012), and Svensson *et al.* (2018). The books are intended for the same group of pupils that are taught according to the same curriculum, so there naturally are many similarities when it comes to contents, layout and physical make-up. They are all 200–300 pages, lavishly illustrated, and printed in full colour throughout.

The illustrations are predominantly visual depictions of technical objects such as machines, vehicles, bridges, and tools. Some of them are photographs while other are detailed sketches or drawings. From a modelling point of view, these are not very interesting. They show what an object looks like, but that is all. A photograph of a car or of a bridge shows what they look

like, but not what their functions are, or how their functions are implemented. Using Hughes' (1997) terminology, the use of those models tends to come to a stop after the *denotation* phase; pupils can identify the model with the phenomenon, but it is of little or no help for analysis of its function, use, effectiveness or efficiency.

From a modelling perspective, more stylised, abstract and symbolic models are more interesting. Those can be found in the textbooks too but are not as numerous as the purely depicting ones. They include circuit diagrams, hydraulic and pneumatic charts, flow charts for computer programs, industrial processes and workflows, and exploded views showing the inner workings of e.g. car engines and household appliances.

Pupils and the textbook models

As stated above, the Swedish technology syllabus states explicitly that pupils should learn how to use certain models to document their own technological work (Skolverket, 2018). According to my interpretation, they should also learn to use and create models during the design process and use models to understand technical phenomena.

Attempts to describe or explain the model concept

Most of the books' attempts to describe or explain the concept of a model are limited to physical models. Fridh (2017, p. 13 f.) describes the need for three dimensional models of products to evaluate ergonomic aspects and suggests that clay, cardboard, and wood can be used. Sjöberg (2012, p. 116 f.) shows three-dimensional models, which he divides into 'functioning models' (model engines that actually move) and 'non-functioning models' (they only look like the real thing, often in a reduced scale). Karlsson & Brink (2017, pp. 14, 16) state that models are important to convey ideas, and that you use classical woodworking tools to make them.

Svensson *et al.* (2018, pp. 26, 29, 39) describe physical models and their use in the design process. In contrast to the other books, symbolic models are mentioned as well. In the chapter about technological systems (p. 78 ff.) we learn that models are commonly used to describe large and complicated systems, such as infrastructure systems. There is also a sketch of a water power plant and its connection to a house, via high voltage wires and a transformer. The caption describes it as a model of a power grid (p. 79).

Abstract, symbolic models are used in all four books, but it is just Svensson *et al.* (2018) that identify them as such. In none of the books, the nature of models as simplified representations is discussed. There are circuit diagrams in the books, but the fact that the wires' resistivity has been omitted is not mentioned. And the reader is not informed that the drainage system around the house and the moisture barrier on the bathroom walls are lacking in the exploded views of houses. Neither the *isolation* nor the *simplification* processes (in the terms of Gerlee & Lundh, 2012) are easily identified. The reader could be misled to believe that the books' models tell the truth (what Hughes, 1997, would call an incorrect *interpretation*).

Pupils' modelling

All four books include chapters about the engineering design process (referred to as 'the design process' or 'the phases of technological development'), including short sections about three-dimensional modelling. They also include longer sections about technical drawing with descriptions of the first angle projection system, edges, hidden edges, symmetry lines, and dimensions. Apart from general mechanical drawings, other types such as construction drawings, drawings for electrical installations etc. are mentioned in passing, as are CAD

systems. The only instructions for actual creation of drawings that are included are for relatively simple, mechanical objects.

Drawings are described as tools for documentation and communication: To just describe an idea orally or in writing does not suffice (Karlsson & Brink, 2017, p. 14). Drawings are used to enable the manufacture of actual products (Svensson *et al.*, 2018, p. 32). All the books mention that physical models (or prototypes) can be used to try out functionality, evaluate ideas and so on. That drawings are often used in a similar manner (Ferguson, 1982) is not mentioned. Notable is also that all books stress the advantages of using a standardised way of making technical drawings, but that none of them use that kind of drawings when describing artefacts in other chapters.

Models to aid pupils' understanding of technical phenomena

Exploded views, simple flowcharts and circuit diagrams are used in all four books to aid pupils' learning about technical artefacts and systems. The mobile telephone is one of few examples that can be found in all four books. It is most likely included because it is a very important piece of everyday technology for many pupils, and because it is included among the examples mentioned in the syllabus (Skolverket, 2018, p. 299).

Comparing the models of mobile telephones and the communication system that they are part of shows important differences in how *isolation* and *simplification* (Gerlee & Lundh, 2012) can be done.

Fridh (2017, p. 87) shows a series of three images depicting the same crossroads with a few buildings around. The first image shows a caller and a base station. Around the base station is a pale blue hexagon, delimiting its cell. A descriptive text states that when calling, the base station first searches for the receiving telephone in the same cell, and then in cells nearby. The second image shows the receiver, who happens to be in an adjacent cell, just on the other side of the road from the caller. The call is connected. The third and final image shows no callers or cells, just an empty crossroads. The caption describes how other base stations take over the call if you or your friend moves out of your respective base stations' cells (p. 87).

Sjöberg (2011, p. 143 f.) shows a stylised landscape with base stations, mobile telephones, communication satellites, a phone exchange, and a typical 1980's telephone. The only textual comment is that 'The mobile telephone sends and receives radio waves. It is in contact with a so-called base station that is placed on a mast or a building. The base station is a transmitter and a receiver that provides contact with the rest of the mobile telephone net' (p. 144, my translation).

Svensson *et al.* (2018, p. 99) shows a photographic image of a base station, a map with three hexagons describing base station cells, with captions. We learn that the base station continuously signals which operator it belongs to, that the telephones receive signals from several stations at once, and that they use the one with the strongest signal.

Karlsson & Brink (2018) is the book that mentions mobile telephones most frequently. They discuss human-computer interaction with the mobile phone as an example. When describing the GPS system, the client is a mobile phone. When writing about new medical technologies, an example concerns a special otoscope, affixed to the camera of a mobile telephone (p. 166). The mobile telephone is present throughout the book, but mainly described as a stand-alone object. Its connection to the internet is mentioned, but not a word about how this is achieved; no radio waves or base stations.

When modelling the mobile telephone system, the books' authors have used different strategies. In the *isolation* phase, Karlsson & Brink (2017) have chosen to include just one phone, while the others have included base stations as well. Svensson *et al.* (2018) isolates one phone and one base station. Fridh (2017) has two phones and three base stations, and even mentions handover from one station to another. The *simplification* phase is similar in all examples: signal strength problems, choosing the right base station, encryption, emergency calls, system clocks, electricity, etc. are omitted. Everything is neat and clean with problem-free radio connections.

Pupils can identify phones and base stations with the models (*designation*). If not reading Karlsson & Brink (2017) they could also understand that the lack of base stations is why mobile telephones do not work in deep cellars (*demonstration*) and why it is rational to take the lift to street level before attempting to make a call (*interpretation*). The authors' chosen *isolation* and *simplification* processes affect which learning that can take place.

Discussion and conclusions

Models and modelling are essential parts of technology and engineering. In the Swedish syllabus (as in many others), models are mentioned, but mainly as methods to document technological work.

In the domain of technology education, studies of modelling and model use are scarce (apart from craft-like aspects of physical model creation). The potential transfer problems of greatly simplified models should be obvious. When pupils learn about highly simplified models, how do we know that they are able to transfer this knowledge to the real system? How could teachers increase the likelihood of successful transfer? How many believe that the textbook illustrations tell the truth? Is it possible to learn how to 'orient [...] and act in a technologically intensive world' (the aim of the Swedish technology subject; Skolverket, 2018, p. 296) without a rudimentary understanding of models and modelling? Further studies are needed.

References

- Committee on Standards for K–12 Engineering Education (2010). *Standards for K–12 Engineering Education?* Washington, DC: National Academies Press. Retrieved from <https://www.nap.edu/catalog/12990/standards-for-k-12-engineering-education> (downloaded 30 March 2019)
- Department of Education [in England] (no year). *Design and Technology Programmes of Study: Key Stage 3*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/239089/SECONDARY_national_curriculum_-_Design_and_technology.pdf (downloaded 30 March 2019)
- Ferguson, E. S. (1992). *Engineering and the Mind's Eye*. Cambridge, MA: MIT press.
- Fridh, J. (2017). *Titano teknik* [Titano technology]. Malmö, Sweden: Gleerups.
- Gerlee, P. & Lundh, T. (2012). *Vetenskapliga modeller – Svarta lådor, röda atomer och vita lögner* [Scientific models: Black boxes, red atoms, and white lies]. Lund, Sweden: Studentlitteratur.
- Hughes, R. I. G. (1997). Models and representation. *Philosophy of Science* 64:325–336.
- Justi, R. S. & Gilbert, J.K. (2002). Modelling, teachers' views on the nature of modelling, and implications for the education of modellers. *International Journal of Science Education*, 24(4), 369–387.
- Karlsson, A. & Brink, H. (2017). *Spektrum teknik* [Spektrum technology]. Stockholm: Liber.

- Ministry of Education [in New Zealand] (no year, will be implemented from 2020). *Technology in the New Zealand Curriculum*. Retrieved from <http://nzcurriculum.tki.org.nz/content/download/167461/1235900/file/Technology%20in%20the%20New%20Zealand%20Curriculum%202017.pdf> (downloaded 30 March 2019)
- Müller, R. (2009). The notion of a model. In: A. Meijers (ed.), *Philosophy of Technology and Engineering Sciences*, pp. 637–664. Amsterdam: Elsevier.
- Skolinspektionen [The Swedish School Inspectorate] (2014). *Teknik – Gör det osynliga synligt!* [Technology: Make the invisible visible!]. Stockholm: Skolinspektionen. Retrieved from <https://www.skolinspektionen.se/sv/Beslut-och-rapporter/Publikationer/Granskningsrapport/Kvalitetsgranskning/Teknik--gor-det--osynliga-synligt/> (downloaded 30 March 2019)
- Skolverket [The Swedish National Agency for Education] (2018). *Curriculum for the Compulsory School, Preschool Class and School-Age Educare*. Originally published 2011, revised in 2018. Stockholm: Skolverket. Retrieved from <https://www.skolverket.se/publikationer?id=3984> (downloaded 30 March 2019)
- Sjöberg, S. (2012). *Puls teknik* [Puls technology]. Stockholm: Natur och kultur.
- Svensson, M., Högfeldt Rudervall, M., Nylén, B., Nylén, B. [there are two different instances of B. Nylén], Olsson, B., Börjesson, G., Chocron, M., & Sjöström, I.-L. (2018). *Teknik direkt* [Technology direct/immediately]. Stockholm: Sanoma utbildning.

The objectives of technology education: a fresh look at the foundations.

Antti Pirhonen

Antti Pirhonen
University of Turku
Finland
antti.pirhonen@utu.fi

ABSTRACT

The primary objective of technology education is traditionally to promote technical abilities. Within educational systems, the approaches in the pursuit of enhancing technical competency stem from various backgrounds. In practice, expertise in learning and teaching have merely instrumental value while the expertise in various forms of technology have a leading role in discussion.

In this position paper we argue that educational view to technology education would result in significant changes in technology education practices, even in the contents of it. Currently the dominating ethos in public discourse, in media, and in the discourse among policy makers stress the importance of technical excellence in economic growth.

Ever since the correlation between economic growth and wellbeing vanished or even turned to negative a couple of decades ago, the uncritical promotion of new technological products and services in all walks of life has become questionable. In technology education, this would imply a new mindset in which technology education is not only seen as an advocate of new technology but as a novel perspective to the relationship among humans, technology and the physical and social environment.

Governments all over the world currently invest heavily on the “digitalization” of schools. Whether we talk about educational technology in general or digital technology in the context of technology education, we argue that the current digital hype is based on beliefs, perceived business opportunities and political intentions. If we aim at shifting the focus to educational objectives or the sustainable development of our societies, we face a discrepancy between dominating policies and the reality.

Keywords: Educational objectives, curriculum, well-being

1. Introduction

Educational systems are the cornerstones of civilizations (Depaepe, 2003). The conceptions of education can never be separated from the cultural context. Therefore, our conceptions about concepts like education and school, even teaching and learning, are highly culture specific. In Thomas Kuhn’s words (Kuhn, 1980), our paradigms are incommensurable. This is a pertinent expression to refer to our vastly differing conceptions about education. For instance, educational systems have been harnessed in some countries to retain class society,

whereas in some other country schools are the primary means to promote equality and welfare society.

Due to this kind of fundamental differences between different cultures, most topics relating to education are complicated to be exposed to international, cross-cultural discussion. Technology education is not an exception. Actually, it combines two controversial concepts, technology and education, resulting in even wider variation of differing interpretations. There are, however, certain clear similarities in how we conceptualise technology education in different cultures.

Rasinen's review of technology education curricula in six different countries reveals that there really exists a number of shared themes across technology education curricula (Rasinen, 2003). However, neither this review nor the curricula explicate the underlying values or rationale. These have to be read between the lines.

In some cases, the values and rationale of the objectives of technology education can be found elsewhere in the curriculum, not in the sections concerning technology education. For instance, in Finland the curriculum is clearly hierarchical. (Here, we refer to the National Core Curriculum of Basic Education (2014), which is the foundation of local curricula.) The first chapters of the document deal with overall objectives and values of Finnish basic education. The more detailed breakdown of objectives and contents of education follow in separate sections for each subject or thematic area. The detailed descriptions are thus obviously subordinate to the overall objectives.

We have previously analysed the discrepancy between the discourse concerning technology and the ambitious overall objectives in Finnish education (Pirhonen, 2010; Pirhonen, 2016). The purpose of the current paper is to analyse our relationship with technology and its reflections in education in general level and in technology education in particular. The trigger for discussion is Rasinen's (2003) analysis.

2. The role of technology in the development of a society

In our approach, basic education is seen as a cornerstone of a society. Therefore, even when discussing technology education, we are unable to dismiss the societal aspects and have a look at the role of technology in our world.

In a very general level, we take technology here as a tool. As Kranzberg (1986) stresses, it is neither good nor bad as such (though continues that it is not neutral either). Throughout the human history, technology has been the foremost means to make life better. Despite the obvious problems caused by the use of technology, it is clear that technology has enabled huge advances in the quality of life.

The progress in the use of technology is hard to measure and illustrate directly. The rise of GDP (Gross Domestic Product) is, however, commonly seen to reflect the application of technology in the pursuit of productivity and economical success. We therefore use here GDP as a more or less direct reflection of the application of technology. The rise of GDP in the industrialised world is often equalled with the risen quality of life. Figure 1 illustrates a typical pair of curves which we want to see. The chart shows the trends of GDP in Finland from 1945 to 2014 (data from updated version of Hoffrén, 2011). We drew in the same chart another statistics, namely infant mortality during the same period.

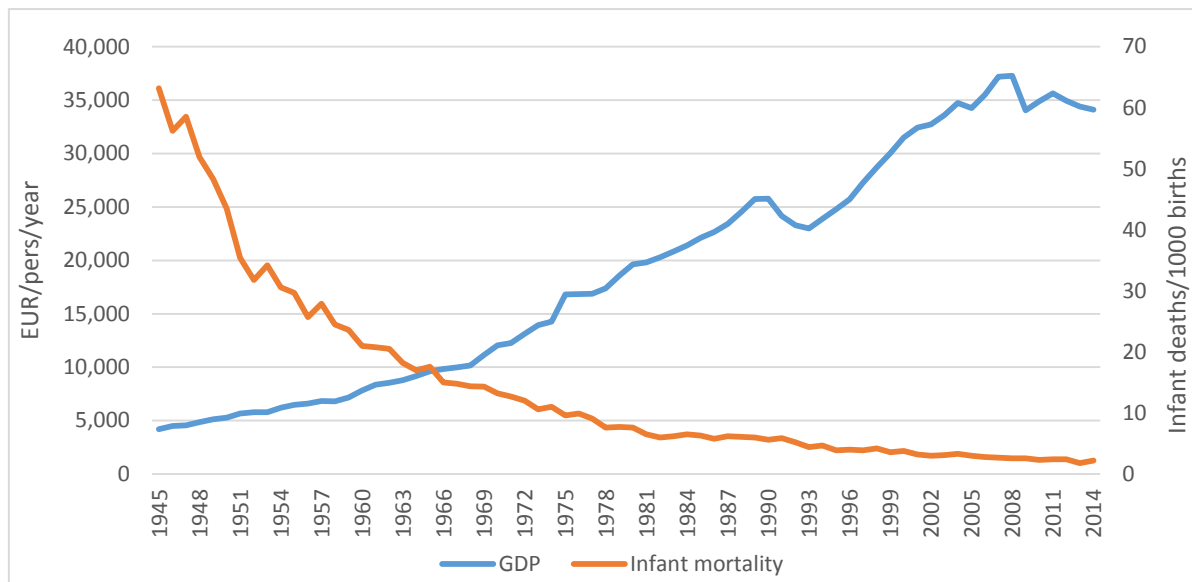


Figure 19. Trends in GDP and Infant mortality in Finland in 1945-2014 (Helsinki: Statistics Finland)

The chart is a nice manifestation of the success in making the world a better place to live, with the help of technology and the resulting wellbeing. The drop of infant mortality has been truly drastic. However, the nice curves look very different if we have a look at GDP in parallel with some more sophisticated measurement of wellbeing. A popular alternative to GDP has been for a couple of decades the so-called Genuine Progress Indicator (GPI) (Cobb, Halstead & Rowe, 1995). GPI is more about well-being than purely monetary qualities. As a gauge, GPI includes traditional economical aspects, but stresses social and environmental qualities when making a synthesis which is supposed to indicate well-being. In other words, if GPI works as intended, it should show the progress of well-being in the given population.

In the western industrial economies, the progress of GDP has been relatively stable since the end of second world war. The trends in GPI, in the contrary, have been much less clear. In order to figure out trends and reflect them with the historical context, we focus on GPI of one single country. In Figure 2, the two curves illustrate the changes of GDP and GPI in Finland from 1945 to 2014. The chart shows how clearly well-being has correlated with economic growth until late 1980's. Until that time, the setting was quite in accordance with what we found when focusing on childhood mortality: The progress in economy, mostly with the help of technology and industrialisation, resulted in higher standard of living.

However, the GPI curve makes a dramatic turn in the late 1980's. From that on, the two curves of Figure 2 point to opposite directions. It appears that since 1989 the growth of economy has no more resulted in well-being. The experts of statistics and economy may find many kinds of explanations for the phenomenon. Whatever the conclusion is, this kind of statistics undoubtedly challenge the fundamental causality between growth of economy and well-being.

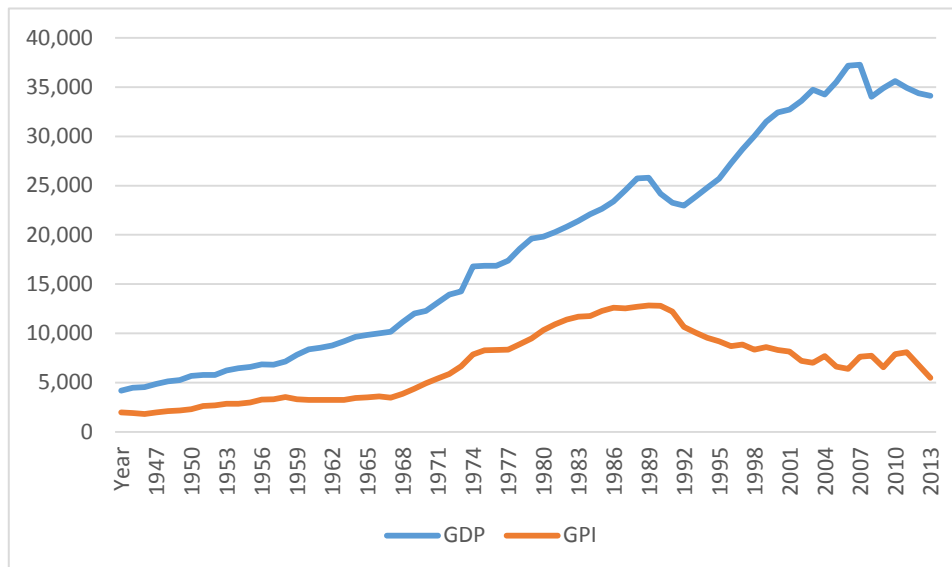


Figure 20. GDP vs. GPI in Finland 1945-2014 (Data retrieved from Hoffrén, 2011)

Going a couple of steps backwards in our reasoning, we finally end up contemplating the role of technology in the big picture. The strong connection between economy and technology cannot be questioned. The growth of GDP is largely due to the development of technology. However, if it turns out that the constant development of technology only results in the growth of GDP, not well-being, what should we think about technology education?

3. The role of technology education in the construction of our societies

If technology does no more generate wellbeing, for what do we need technology education? This question is based on over-simplification of the conclusions made from the relationship between economy and wellbeing. If I'm seriously ill and have to go to a hospital, I'm very likely to praise the newest medical technology. Similar kinds of examples are not difficult to be found. The assumed negative correlation between economic growth and wellbeing is currently only a statistical relationship, not causal. In other words, we really don't know why the development of technology (or actually GDP) has not have positive effect in wellbeing for a while. Most of the discussion in the topic are vague speculations. In order to find a sound basis for discussions, we encourage to keep *technology* conceptually apart from *technological products*.

In a contemporary society we deal with technology all the time. When talking about technology in everyday context we often refer to – not technology as such – but digital consumer products. The recent rapid change of forms of digital consumer products has indeed stolen much of the attention of media and public, thus making “technology” almost a synonym for fashionable digital products. For sure, digital technology has a rapidly growing number of application areas in consumers' everyday life.

We have previously analysed (Pirhonen, 2010; Pirhonen, 2016) how the demands to include technology in curricula appear somewhat disconnected statements. There clearly has been pressures to express positive attitude towards technology, but finally there was little, if any, justification in our sample curricula (The National Core Curriculum of Basic Education, see Finnish National Board of Education, 2016). There was a clear demand to teach technology and to teach with the help of technology, but no answers to questions like why or even what (here again, we refer to information and communication technology).

The practical implications of this can already be seen in the rapid change of not only school life but also the culture of young people in general. The excessive consumption of electronics and related services hardly indicates sophistication as such. For technology educators, in turn, the current situation is a challenge. How to bring attitudes toward technology to healthy basis?

References

- Cobb, C., Halstead, T. & Rowe, J. (1995). If the GDP Is Up, Why Is America Down? *The Atlantic Monthly* 264(4), 59-78.
- Depaepe, M. (2003). The school, cornerstone of modern society. In: Depaepe, M. (Ed.) *Between educationalization and appropriation: Selected writings on the history of modern educational systems*. Leuven (Belgium): Leuven University Press, 23-34.
- Finnish National Board of Education (2016). *National Core Curriculum for Basic Education 2014*. Unofficial translation. Helsinki: Finnish National Board of Education.
- Hoffrén, J. (2011). Gross Domestic Problem: The Politics Behind the World's Most Powerful Number. *Future Trends of Genuine Welfare in Finland*. In: Lakkala H. and Vehmas, J (eds). *Trends and Future of Sustainable Development*. Proceedings of the Trends and Future of Sustainable Development conference. Tampere, Finland. 9-10 June: 305-312. Available at https://www.utu.fi/fi/yksikot/ffrc/julkaisut/e-tutu/Documents/eBook_2011-15.pdf.
- Kranzberg, M. (1986). Technology and History: "Kranzberg's Laws". *Technology and Culture* 27(3), 544-560
- Kuhn, T. S. (1970). *The structure of scientific revolution*. Chicago (ILL): University of Chicago Press. 2nd ed., enl.
- 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.
- Pirhonen, A. 2016. The ethos of the discourse concerning the future and technology. Proceedings of PATT2016 - Technology Education for 21st Century skills. Utrecht, the Netherlands, August 23-26. <https://hubl.hu.nl/session/conference-program-papers>
- Rasinen, A. 2003. An analysis of the technology education curriculum of six countries. *Journal of Technology Education* 15(1), 31-47

Developing a Methodological Approach to Measure Cognitive Load during Complex Problem Solving.

Clodagh Reid, Conor Keighrey, Rónán Dunbar, Niall Murray, Jeffrey Buckley.



Clodagh Reid
Athlone Institute of Technology

Ireland
c.reid@research.ait.ie



Conor Keighrey
Athlone Institute of Technology

Ireland
c.keighrey@research.ait.ie



Rónán Dunbar
Athlone Institute of Technology

Ireland
rdunbar@ait.ie



Niall Murray
Athlone Institute of Technology

Ireland
nmurray@research.ait.ie



Jeffrey Buckley
Athlone Institute of Technology, KTH Royal Institute of Technology

Ireland, Sweden
jbuckley@ait.ie

ABSTRACT

Problem solving is an important element of engineering and technology disciplines and spatial ability contributes to learners' success in problem solving in these areas (Wai, et al., 2009). As excessive cognitive load can impede an individual's capacity to process information (Kirschner, Paas & Kirschner, 2009) it is posited that higher levels of spatial ability may reduce the cognitive load experienced when problem solving and thus support increased learner performance and capacity to learn from problem solving episodes. Based on this hypothesis, there is a need to establish appropriate methods to measure cognitive load in educational contexts. Using Cognitive Load Theory (Sweller, 1988) as a theoretical framework, this paper presents a pilot study of a methodological approach to measure cognitive load experienced in real-time during complex problem solving activities through the use of physiological sensors. Postgraduate students (n=26) were administered the Tower of Hanoi, a complex problem solving task (Eielts et al, 2018). While completing the task, physiological sensors were worn by participants on their non-dominant hand capturing details of electrodermal activity, which is an indicator of cognitive load experienced in real time (Setz, et al., 2010). Subjective data on the levels of cognitive load experienced was also captured following the task, where participants completed a 9-point Likert-type item. The analysis of the data for this study illustrated that through the use of a physiological sensor and application of novel time monitoring software, the electrodermal activity of an individual can provide an insight into their experience whilst problem solving. This approach may present a valid way to capture cognitive data of students throughout authentic problem solving scenarios which would support the determination of variables underpinning success.

Keywords: Cognitive load, Spatial ability, Problem solving, Physiological sensors.

Introduction

Cognitive load theory describes how the mental effort experienced by an individual when processing information can impact their capacity to process that information effectively (Kirschner, et al., 2018; Sweller, 2011, 2010). Through impacting processing capacity, cognitive load can affect the individual's performance on a task (Kirschner, et al., 2018; Paas, et al., 2004; Van Gog, et al., 2010) thus impeding their learning. This is of particular importance to teaching and learning as educators strive to support learners in understanding new concepts. Within engineering and technology education, learners experience a variety of problems and problem types to aid in acquiring and contextualising technical and transversal competencies (Buckley, et al., 2018; Kirschner, et al., 2009; Schoenfeld, 1983). The problems learners experience can vary in how well or ill-defined they are, and also in terms of being open or closed-ended. Therefore, these problems require learners to adopt a variety of approaches to solve them (Reid, et al., 2018).

Throughout problem solving, cognitive load may be experienced for a number of reasons, such as a lack of knowledge or the way through which the problem is communicated (Kirschner, et al., 2018; Paas, et al., 2004, 2003). The effects of cognitive load on problem solving in education have been explored on both an individual and collaborative level (Kirschner, et al., 2018; Kirschner, et al., 2009; Paas, et al., 2004) as problem solving can take place in either format. Subjective measures of cognitive load such as the mental effort Likert-type scale developed by Pass (1992) have become common measures of cognitive load in studies as they are unobtrusive and offer valid and reliable indications of overall cognitive load experienced during a task (Sweller, 2011). Following technological advancements, objective measures such as electroencephalography (EEG), pupillometry, eye-tracking and heart-rate (HR) measurement have been explored for their capacity to measure the cognitive functions of an individual during a task (Antonenko, 2010; Palinko, 2010; Sweller, 2011). This paper presents a methodological approach to measure cognitive load throughout complex problem solving in an unobtrusive manner through the use of a medical grade physiological sensor, the Empatica E4 sensor. Specific emphasis was placed on determining the capacity of the E4 sensor to capture precise data in relation to the cognitive load experienced by individuals in real time. As this study is based in technology and engineering education, the nature of problem solving, spatial ability, and cognitive load, and the interaction of these three variables are critical factors.

Problem solving

Tasks or exercises become problems when an individual does not know how to go about solving them (Buckley, et al., 2018) and therefore problems occur in a variety of ways in engineering and technology education. In solving problems, learners can use various methods and approaches to develop appropriate solutions (Jonassen, et al., 2009; Reid, et al., 2018) and due to the prevailing treatment of knowledge in technology and engineering education, they may utilise heuristics to reason about the problem (Buckley, et al., 2018). While working to understand the information presented in a problem and to identify an appropriate means to solve it, learners may experience substantial cognitive load due to their limited processing capacity (Marois, & Ivanoff, 2005). This is a significant consideration for educators and highlights the importance of supporting the learner with appropriate instruction throughout the problem solving process to limit the effects of cognitive load (Paas, et al., 2004, 2003). From a foundational research perspective, there is a need to consider the nature of problems that occur in context, but to work with problems that are a valid indicator of an important construct. Therefore to study problem solving in context with a novel instrument, it can be necessary to use abstract problems first prior to working with contextually validated authentic problems.

Spatial Ability

Spatial ability has been attributed to success in STEM disciplines (Uttal & Cohen, 2012) and is noted for its impact on student retention within these subject areas (Sorby, 2001). It has also been demonstrated to correlate with performance in technology and engineering

education specifically (Buckley, et al., 2019; Lin, 2016; Sorby, et al., 2013). Based on these investigations and the role of spatial ability in problem solving in engineering and technology, the investigators postulated that spatial ability may influence the cognitive load experienced by students when problem solving throughout engineering and technology education. In considering the circumvention-of-limits hypothesis (Hambrick, et al., 2012) which describes the interaction between domain knowledge and generic cognitive abilities of disciplinary importance in terms of problem solving performance, there is a clear need to establish levels of spatial ability in participants in problem solving research in the context of technology and engineering education.

Cognitive load

As discussed, cognitive load theory proposes that the load experienced during information processing can impact the successful processing of information and thus influence the performance of the individual on the task (Kirschner, et al., 2018; Sweller, 1988). Cognitive load can be further classified in terms of extraneous, intrinsic and germane cognitive load (Paas, et al., 2003; Sweller, 2010).

Germane cognitive load is outlined as the resources of working memory which are used to deal with intrinsic cognitive load (Kirschner, et al., 2018). Intrinsic cognitive load relates to the essential complexity of the information which must be processed (Sweller, 2010). Cognitive load that is unnecessary and interferes with the processing of information is called extraneous cognitive load (Paas, et al., 2003). Extraneous cognitive load can be caused by the way the information is presented to an individual (Kirschner, et al., 2018; Paas, et al., 2003; Sweller, 2011). In considering a methodological approach to measure cognitive load, there is a need to consider if there is a specific type of cognitive load which is the target of measurement, or if the agenda is to elicit the degree of experienced cognitive load as a whole.

Methodology Development

Measuring Cognitive Load

Subjective Measures

There are various measures which can be used to investigate the cognitive load experienced by individuals when carrying out a task, such as the NASA-TLX and a number of Likert scale approaches (Leppink & Van Merriënboer, 2015; Van Merriënboer & Sweller, 2005; Plas & Kalyunga, 2018). The NASA-TLX is outlined as a direct subjective measure of cognitive load (Plas & Kalyunga, 2018), making it a potentially suitable mechanism to measure self-reported cognitive load of participants in the study. Mental effort scales and task difficulty scales, also included in the NASA-TLX, are outlined throughout cognitive load literature as measures of overall cognitive load (Leppink & van Merriënboer, 2015; Plas & Kalyunga, 2018), which is the focus of this paper.

Paas (1992) developed and validated a 9-point Likert-type item to evaluate the overall cognitive load experienced by an individual (Leppink & van Merriënboer, 2015; van Merriënboer & Sweller, 2005). Additionally, recent investigations have explored the capacity of similar Likert-type items to accurately measure extraneous, intrinsic and germane cognitive load (Leppink, et al, 2014, 2013). In developing the 9-point Likert-type items for this study the investigators sought to measure overall cognitive load, difficulty experienced with the task, concentration and stress to determine factors that may influence participant performance. Stress can also be measured through objective measures of cognitive load.

Objective Measures

Various sensors and software have been used to investigate the cognitive load experienced by individuals throughout activities. These include pupilometry, eye-tracking, electroencephalography (EEG), heart rate (HR) measurements (Sweller, 2011) and electrodermal activity (EDA) measurements (Keighrey, et al., 2017; Setz, et al., 2010). Recent works have demonstrated that measures of EDA can be used to monitor cognitive load

experienced by individuals during arithmetic and reading tasks (Nourbakhsh, et al., 2012) and of individuals using a driving simulator (Son & Park, 2011). EDA has also been evaluated for the capacity to discriminate between stress and cognitive load experienced with an activity (Setz, et al., 2010).

The use of physiological sensors can often impact natural interaction with a problem solving task. To reduce such influence, a non-intrusive device was selected. More specifically an Empatica E4 wristband. The Empatica is a medical grade device which captures physiological measures of EDA, HR, blood volume pulse (BVP), skin temperature, and movement data (accelerometer). In measuring physiological responses, it is pivotal that baseline measurements are obtained so that they can be compared to the readings when the individual is exposed to the stimulus (Setz, et al., 2010). Typically, baseline measurements range between 2 and 20 minutes (Alvarsson, et al., 2010; McDuff, et al., 2014; Setz, et al., 2010). However, recent works have highlighted 5 minutes as an appropriate duration as it offers sufficient time for the individual to relax following their arrival at the session and for baseline measures to be gathered (Alvarsson, et al., 2010).

Problem Solving Task

The investigators sought to examine the cognitive load experienced by individuals during a complex problem solving activity. As this was a pilot study and participants would come from various backgrounds with different technical knowledge bases, the investigators sought a general problem with no/minimal discipline-specific knowledge required to solve it.

Having explored various styles of problems the Tower of Hanoi (TOH) was identified as the problem solving task that would be used for this study as it is representative of a complex problem solving task (Eielts et al, 2018). The difficulty of the task can also be increased through the addition of discs which would allow the investigators to monitor the cognitive load experienced between an easier and more difficult problem solving activity.

The TOH can be solved through an optimal number of moves (Eielts, et al., 2018; Stewart & Eliasmith, 2011) making it necessary for the number of moves made by participants to be monitored throughout the task. In order to monitor the moves made by participants a software programme was developed whereby the participants' engagement with the task could be tracked. A start point for the activity was incorporated into the software so that the time could be observed between participants being told to begin the task and the first move being made. Each move made by participants could be inputted into the software. Through incorporating this feature the time taken between moves could be time-mapped onto the sensor data to monitor the physiological responses of participants between moves. This would allow for a robust analysis of the data following the completion of the study.

Methodology Implementation

Participants

Postgraduate students (n=26) were invited to take part in the study. The participants consisted of 13 males and 13 females with ages ranging between 21 and 48. Participation in the study was voluntary and individuals were entered into a draw for a €20 voucher as an incentive for participation. For the purposes of this paper, only 2 of the participants are discussed. The selection criteria are discussed below.

Spatial Ability Testing

The Purdue Spatial Visualisation Test: Rotations (PSVT:R) (Bodner & Guay, 1997), Surface Development test (SDT) and Paper Folding test (PFT) (Ekstrom, et al., 1976) were used to measure participant spatial ability. A composite z-score of each of the spatial tests were derived for each of the participants. Z-scores were used as the purpose of this approach is to examine participants with varying levels of spatial ability within the group, rather than to compare the results to international datasets. Participants' scores on each of the three spatial

tasks were converted to standardised z-scores relative to the entire cohort and then averaged to determine a single z-score per participant.

Sensor Setup

As per the device recommendations, participants were fitted with the Empatica E4 on the non-dominant. The sensors for EDA were positioned in-line with the joint of the second and third finger at the wrist (Figure 1) to allow for an accurate and precise reading of the physiological response. Participants were instructed to relax for a period of 5 minutes to obtain baseline measurements of EDA.

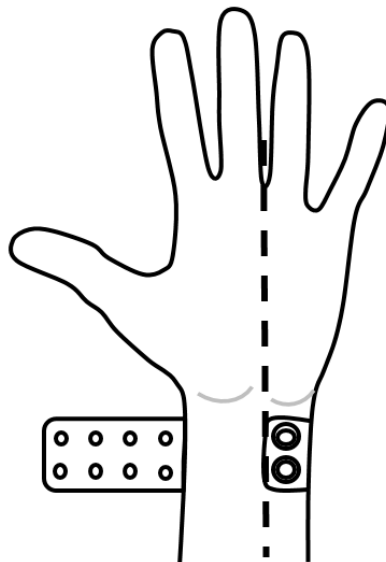


Figure 21. Empatica E4 sensor set-up

Problem Introduction

Following the baseline period of 5 minutes, participants were presented with the 3-disc TOH task. They were asked to indicate whether they had seen the problem before and if they subsequently knew how to solve it. These indications did not act as an element of selection criteria. Once this was complete, the instructions for the task were explained to participants as follows:

‘The goal of the task is to get the arrangement of 3 discs on the left-most peg to the right-most peg. The discs must be arranged in the same order i.e. largest on the bottom to smallest on the top. There are two conditions:

- 1. Only one disc can be moved at a time from one peg to another*
- 2. A larger disc cannot be placed on a peg that already contains a smaller disc’*

Participants were provided with the opportunity to ask questions to ensure that they understood the task. They were then instructed to begin the problem.

Problem Solving Task

Throughout the problem solving task participants were recorded. A video camera was setup and focused specifically on participant hand gestures. This ensured a level of anonymity was achieved, in addition to providing opportunity to capture the interaction with the activity.

In parallel to this, a novel software was developed to objectively capture user interaction. The software solution automated the capture of task completion (time), interaction time, and number of moves taken to complete the task. The objective of this was to create an accurate measure of user performance.

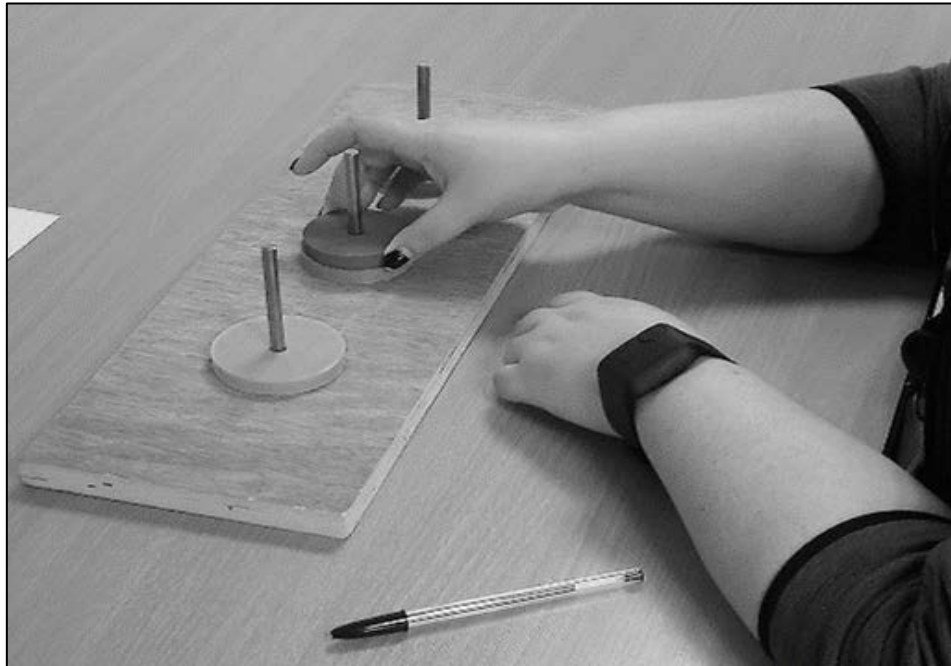


Figure 22. Task setup.

Each move was marked by the investigator electronically with the final move concluding the time tracking on this session. A move was counted when the disc was placed on a peg and released by the participant.

Having completed the task participants were asked to indicate on a 9-point Likert-type item the amount of mental effort, difficulty, stress and concentration they experienced throughout the task. When the item was completed, participants were presented with the second problem, the 4-disc TOH. The same process was repeated for the 4-disc problem.

Results

The data presented in Table 1 represents the mean (M) and standard deviation (SD) of self-reported mental effort, difficulty, stress and concentration experienced by all participants ($n = 26$) with the 3- and 4-disc TOH tasks. The table also includes the means and standard deviations of the number of moves made by participants during the 3- and 4-disc TOH.

Table 1. Mean and standard deviation of participant responses and performance.

	3 Disc Problem		4 Disc Problem	
	M	SD	M	SD
Mental Effort	3.46	1.68	5.27	1.61
Difficulty	2.96	1.37	5.08	1.55
Stress	2.19	1.33	3.69	1.83
Concentration	4.81	1.67	5.73	1.56
Moves	8.12	2.29	28.12	12.09

Participants were categorised in terms of spatial scores. For each participant a spatial z-score was determined based on their percentage score on the PSVT:R, SDT and PFT. Participant 16 had the highest overall spatial score ($z = 1.33$), while participant 20 had the lowest overall spatial score ($z = -1.89$) of the 26 participants. The remaining data documented will focus on participant 16 and 20. Table 2 presents the z-scores of these two participants on the self-

reported 9-point Likert-type item. The z-scores outline where each of these participants ratings sit within the overall cohort with respect to the mean and standard deviation.

Table 2. Self-report data

Participant	Mental Effort	Difficulty	Stress	Concentration	No. of Moves
<u>3 Disc Tower of Hanoi</u>					
16	0.92	0.03	-0.90	0.11	-0.05
20	-0.87	-0.70	-0.14	-0.48	-0.49
<u>4 Disc Tower of Hanoi</u>					
16	-0.17	-0.05	-1.47	0.17	-0.75
20	0.45	0.60	0.17	0.17	1.56

The EDA data of participants was evaluated relative to their problem solving performance. In order to identify EDA events of importance within the data of each participant, a time threshold for moves on the 3- and 4-disc TOH was determined. Any time that was below or equal to this threshold was considered as a normal time spent on a move and anything above this threshold was considered as a large time spent on a move. Thresholds were determined for each participant by calculating the mean time spent on a move, standard deviation of time for a move and adding the standard deviation to the mean. Table 3 presents the mean, standard deviation and threshold of time for participants 16 and 20.

Table 3. Time threshold for participant moves

Participant	Move Time (M)	Move Time (SD)	Move Time Threshold
<u>3 Disc Tower of Hanoi</u>			
16	8.205	15.750	23.955
20	3.507	1.327	4.834
<u>4 Disc Tower of Hanoi</u>			
16	4.735	4.120	8.855
20	3.267	1.838	5.104

The EDA data collected during the 3- and 4-disc TOH for participants 16 and 20 is presented in Figures 3, 4, 5 and 6. The values displayed for EDA are z-scores.

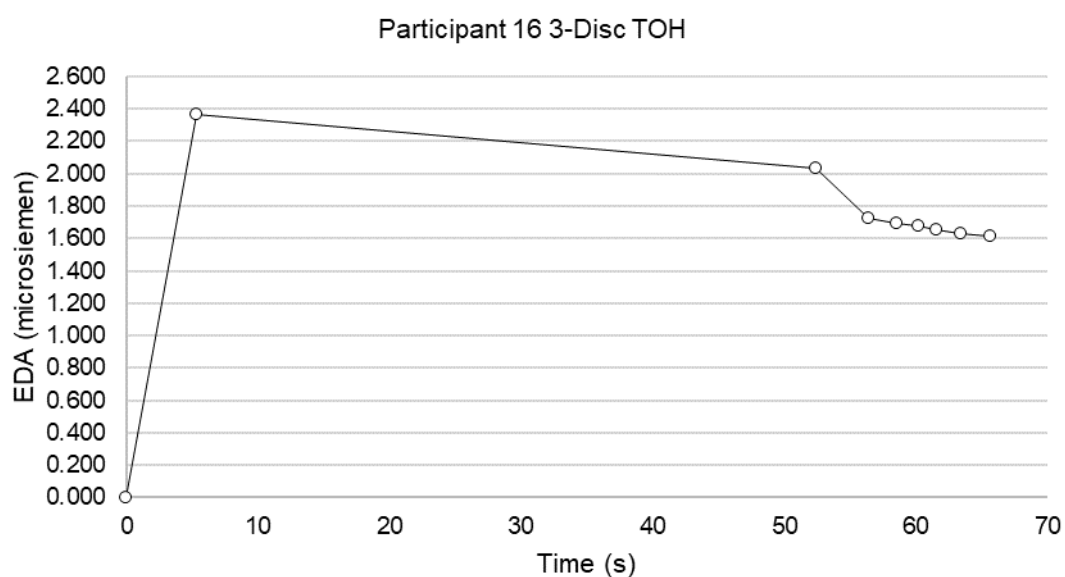


Figure 23. Participant 16 EDA Data during 3-disc TOH

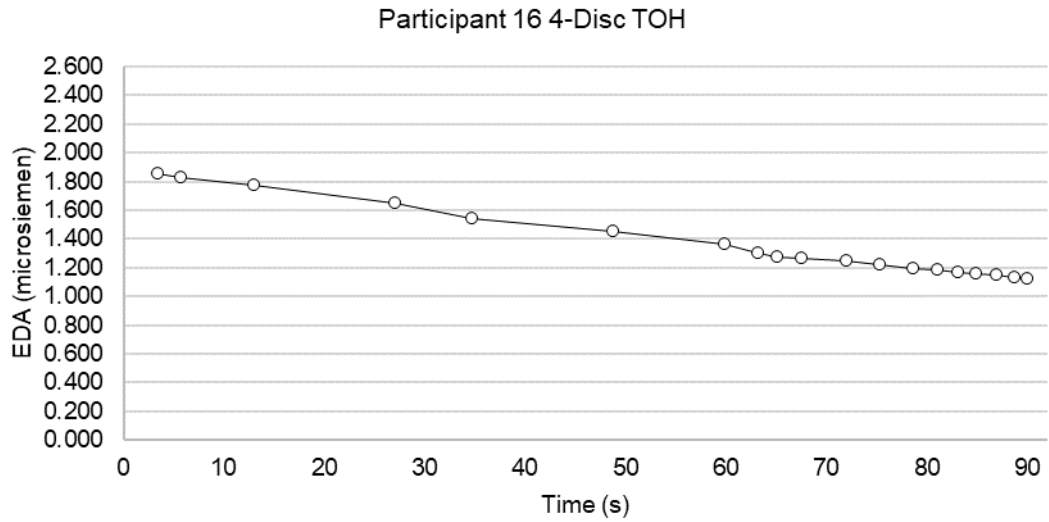


Figure 24. Participant 16 EDA during 4-disc TOH

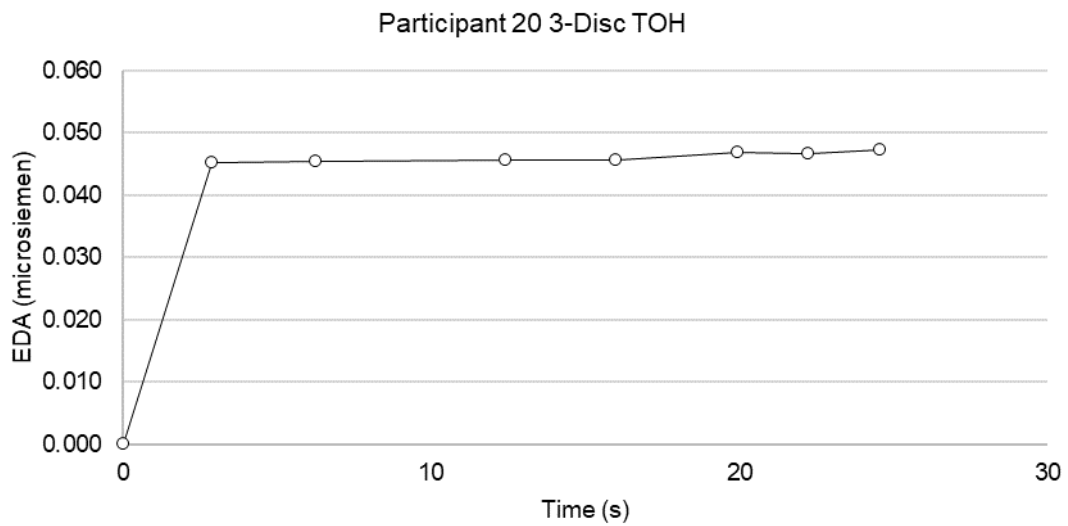


Figure 25. Participant 20 EDA during 3-disc TOH

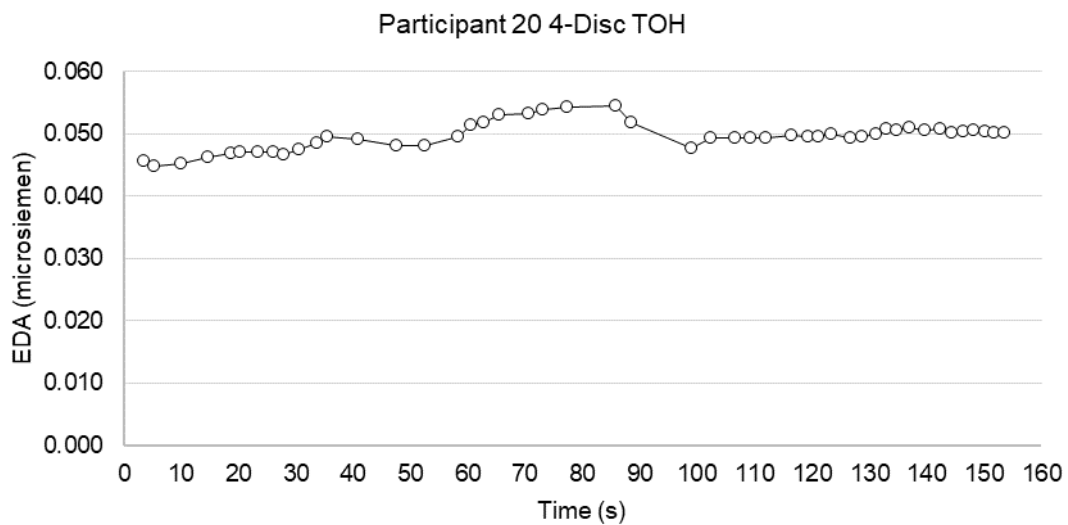


Figure 6. Participant 20 EDA during 4-disc TOH

Discussion

The purpose of this investigation was to develop a methodological approach to objectively measure the cognitive load experienced by individuals throughout a problem solving task. The Empatica E4 physiological sensor was used to measure the EDA of participants during the task as increased EDA can be indicative of increased mental effort (Setz, et al., 2010). Overall percentage spatial scores of the participants were used to organise the data. Participant 16 and 20 were identified to have the highest and lowest spatial score respectively of the 26 participants. The EDA data for these participants was then analysed.

Through evaluating the EDA data of participants it was critical that a baseline measurement was obtained so that the EDA of the individual in a relaxed state could be compared to the data collected during the problem solving episode. The first point on the graphs in figure 3 and 5 represents the baseline EDA of participants 16 and 20. The second point on these graphs represents the time taken by participants between being instructed to begin the task and making their first move.

Through capturing the time taken between moves using a software programme, investigators were able to map these times to the EDA data. The time thresholds, presented in Table 3, were then used to determine points of interest within the EDA data where there was a large delay between moves relative for each person. With participant 16, there was an initial increase in EDA with the 3-disc TOH. Following a large delay, EDA continued to decrease throughout both problem solving tasks. Participant 20 did not have much variation in EDA with the first problem, however, there was an increase and variation during the second problem.

Investigating the data in this manner provides an insight into the experience of a student during problem solving. This approach also affords the capacity to isolate a moment within the problem to examine the reason it may have had an effect on the individual. The use of a physiological sensor to monitor EDA during problem solving may inform educational practice by supporting educators in examining pedagogical strategies relative to individual learners' cognitive abilities, exploring the effects of group dynamics in design activities, and identifying potentially unknown sources of cognitive load and stress in students and teachers. The future of this work will focus on further analysis of the data and monitoring the cognitive load experienced by students throughout authentic engineering and technology problems.

References

- Antonenko, P., Paas, F., Grabner, R., & Van Gog, T. (2010). Using electroencephalography to measure cognitive load. *Educational Psychology Review*. 22(4), 425-438.
- Bodner, G. M., & Guay, R. B. (1997). The purdue visualization of rotation test. *The Chemical Educator*. 2(4).
- Buckley, J., Seery, N., & Canty, D. (2018). Investigating the use of spatial reasoning strategies in geometric problem solving. *International Journal of Technology and Design Education*. 341-362.
- Eielts, C., Pouw, W., Ouweland, K., Van Gog, T., Zwaan, R. A., & Paas, F. (2018). Co-thought gesturing supports more complex problem solving in subjects with lower visual working-memory capacity. *Psychological research*. 1-12.
- Ekstrom, R. B., French, J. W., & Harman, H. H. (1976). *Manual for kit of factor-referenced cognitive tests*. Princeton, NJ: Educational Testing Service.
- Hambrick, D.Z., Libarkin, J.C., Petcovic, H.L., Baker, K.M., Elkins, J., Callahan, C.N., Turner, S.P., Rench, T.A. & LaDue, N.D. (2012). A test of the circumvention-of-limits hypothesis in scientific problem solving: The case of geological bedrock mapping. *Journal of Experimental Psychology: General*. 141(3). 397-403.
- Hart, S. G. (2006). NASA-task load index (NASA-TLX); 20 years later. In *Proceedings of the human factors and ergonomics society annual meeting*. 50(9), 904-908.
- Keighrey, C., Flynn, R., Murray, S., & Murray, N. (2017). A QoE evaluation of immersive augmented and virtual reality speech & language assessment applications. In 2017

- Ninth International Conference on Quality of Multimedia Experience (QoMEX)*. IEEE. 1-6.
- Kirschner, F., Paas, F. & Kirschner, P. A. (2009). A cognitive load approach to collaborative learning: United brains for complex tasks. *Educational psychology review*. 21, 31-42.
- Kirschner, P. A., Sweller, J., Kirschner, F., & Zambrano, J. (2018). From cognitive load theory to collaborative cognitive load theory. *International Journal of Computer-Supported Collaborative Learning*. 13(2), 213-233.
- Leppink, J., & van Merriënboer, J. J. (2015). The beast of aggregating cognitive load measures in technology-based learning. *Educational Technology & Society*. 18(4), 230-245.
- Lin, H. (2016). Influence of design training and spatial solution strategies on spatial ability performance. *International Journal of Technology and Design Education*. 26(1), 123-131.
- Marois, R. & Ivanoff, J. (2005). Capacity limits of information processing in the brain. *Trends in Cognitive Sciences*. 9 (6), 296-305.
- Nourbakhsh, N., Wang, Y., Chen, F., & Calvo, R. A. (2012). Using galvanic skin response for cognitive load measurement in arithmetic and reading tasks. In *Proceedings of the 24th Australian Computer-Human Interaction Conference* (420-423). ACM.
- Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational psychologist*. 38(1), 1-4.
- Paas, F., Renkl, A., & Sweller, J. (2004). Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. *Instructional science*. 32(1), 1-8.
- Palinko, O., Kun, A. L., Shyrokov, A., & Heeman, P. (2010). Estimating cognitive load using remote eye tracking in a driving simulator. In *Proceedings of the 2010 symposium on eye-tracking research & applications*. 141-144.
- Reid, C., Dunbar, R., & Buckley, J. (2018). A preliminary model of problem categorisation to explore the cognitive abilities required for problem solving in engineering education. In N. Seery, J. Buckley, D. Canty, & J. Phelan (Eds.), *PATT2018: Research and Practice in Technology Education: Perspectives on Human Capacity and Development*. Westmeath, Ireland: Athlone Institute of Technology.
- Schoenfeld, A. (2009). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. *Colección Digital Eudoxus*. (7).
- Schoenfeld, A. (1983). The wild, wild, wild, wild, wild world of problem solving (A review of sorts). *For the Learning of Mathematics*, 3(3), 40–47.
- Setz, C., Arrich, B., Schumm, J., La Marca, R., Tröster, G., & Ehlert, U. (2010). Discriminating stress from cognitive load using a wearable EDA device. *IEEE Transactions on information technology in biomedicine*. 14(2), 410-417.
- Son, J., & Park, M. (2011). Estimating cognitive load complexity using performance and physiological data in a driving simulator. In *Adjunct Proceedings of the Automotive User Interfaces and Interactive Vehicular Applications Conference*.
- Sorby, S. A. (2001). Improving the Spatial Skills of Engineering Students: Impact on Graphics Performance and Retention. *Engineering Design Graphics Journal*. 65(3), 31-36.
- Sorby, S., Casey, B., Veurink, N., & Dulaney, A. (2013). The role of spatial training in improving spatial and calculus performance in engineering students. *Learning and Individual Differences*. 26, 20-29.
- Stewart, T., & Eliasmith, C. (2011). Neural cognitive modelling: A biologically constrained spiking neuron model of the Tower of Hanoi task. In *Proceedings of the Annual Meeting of the Cognitive Science Society*. 33(33).
- Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive science*. 12(2), 257-285.
- Sweller, J. (2010). Element interactivity and intrinsic, extraneous, and germane cognitive load. *Educational psychology review*. 22(2), 123-138.
- Sweller, J. (2011). Cognitive load theory. In *Psychology of learning and motivation*. 55, 37-76.
- Uttal, D. H., & Cohen, C. A. (2012). Spatial thinking and STEM education: When, why, and how?. In *Psychology of learning and motivation*. 57. 147-181.

- Van Gog, T., Paas, F., & Sweller, J. (2010). Cognitive load theory: Advances in research on worked examples, animations, and cognitive load measurement. *Educational Psychology Review*. 22(4), 375-378.
- Van Merriënboer, J. J., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational psychology review*. 17(2), 147-177.
- Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*. 101(4), 817.

The academic study of food in the English curriculum for pupils aged 16-18 years: its demise and future prospects.

Marion Rutland



Marion Rutland
University of Roehampton
UK
m.rutland@roehampton.ac.uk

ABSTRACT

The paper refers to the introduction of the teaching of food in English schools in the mid-19th Century as cookery, domestic science, housecraft and home economics to food technology in the National Curriculum (DES, 1990). Current issues discussed include the loss of the General Certificate of Education (GCSE) Food Technology, the introduction of a GCSE Food Preparation and Nutrition for pupils aged 16 years and the demise of an A Level Food Technology course for pupils aged 16-18 years. The course content of food related undergraduate courses; student's reasons for studying them and the A Level subjects they studied (Rutland & Jackson, 2014a, 2014b) were reviewed. A draft new A Level Food course, developed by the author, and a 'Survey Monkey' online questionnaire was used to explore the responses of professional people involved in food education in schools. The intention was to reintroduce a pathway into food related undergraduate courses in preparation for professional and research careers and employment in a 'knowledge economy'. The small scale research, based on 67 responses, indicated a 100% agreement that an A Level Food examination should be available, though with some variations in the suggested title and content of the course. Areas such as the composition and nutrition of foods, the preservation of food to prolong shelf-life, preventing spoilage and contamination and the impact of new technologies were well received. However, there was less support for handling and preparation of food materials, the influences of industry and applied science and technology. The results indicate that a larger and broader perspective is need to take into account the specific needs for training in food related areas not addressed by courses at a similar level. Including the views from university admissions tutors, examination boards and the Department for Education (DfE), for a course that provides progression and entry to higher education and future employment opportunities.

Key words: food teaching, food technology, academic examination courses for pupils aged 18 years, undergraduate courses.

Introduction

Food was first introduced into the English state school curriculum in the mid-19th Century. It went through a range of title changes including cooking, domestic science, housecraft, home economics and catering until the introduction of Technology including design and technology (D&T) in the National Curriculum (DES, 1990) and the integration of food as food technology within D&T. Food technology was compulsory for pupils aged 5 to 16 years and available as an option for pupils aged 16-18 years. This included a GCSE Food technology for pupils aged 16 year and an A Level Food technology examination for pupils aged 18 years. They provided a pathway into higher education for pupils interested in following food related courses and they remained in place until 2016/2017.

Following the review of the D&T curriculum, all GCSE and A Level subjects (DfEa, 2014) were reformed and it was decided to develop a combined *GCSE Cooking and Nutrition*, with a name change later to *GCSE Food Preparation and Nutrition* (DfE, 2015). The new qualifications focused on ensuring students acquire a good understanding of food and nutrition together with excellent cooking skills (ibid: 6-7). The draft GCSE Subject Content for D&T (DfEb, 2014) did not include food as material. All the former food courses, such as home economics, hospitality and catering and food technology were to be addressed through one examination course. A new A Food Technology level course, providing a pathway for pupils aged 18 years and progression to higher education courses, was not developed, as a number of high quality vocational qualifications; confectionary and butchery were available (DfEa, 2014).

It can be argued that changing 21st Century life styles and an increasing availability of ready prepared food products with the growth of the food industry have led to changing eating habits and patterns. The food and drink industry is the UK's largest manufacturing sector, contributing £28.2bn to the economy annually and employing 400,000 people (Food & Drink Federation (fdf), 2019). That, in addition to developing cooking skills, food teaching should focus on developing pupils' knowledge and understanding of all aspects of food, including food science and technology, social, political and economic food issues (Lawson, 2013; Rutland & Owen Jackson, 2013, 2014a). The new GCSE examination attempts to cover the general and vocational aspects of food education and the 'life skill' of cooking. It focuses on developing food skills and prepares pupils to cook food at home and employment in the hospitality and catering industry, but there are questions whether it provides progression to other employment and food-related course in higher education.

Course content and entry requirements for studying food in higher education.

Research carried out by Rutland, Owen-Jackson (2014a) explored the appropriateness of the food technology school curriculum for pupils as preparation for progression to higher education. The research question was:

'What is the course content of university food-technology related course?'

Data was collected by a web search of university-level food technology course content and course information through The Complete University Guide

<http://www.thecompleteuniversityguide.co.uk/league-tables/rankings?s=Food%20Science>.

Thirty six universities were listed; the top ten were selected for consideration. Only undergraduate courses were considered related to food science, aspects of food technology and food and nutrition and these three categories were used for analysis. Each course name, entry requirement and content was noted (Table 1.)

Entry requirement	Content
Food Technology: 1 course	
Reading University: 2 core sciences (chemistry, physics, biology, mathematics) Other science further mathematics, statistics, psychology, geography, environmental science, applied science and geology Food technology not mentioned	Year 1: Foundations of chemistry, microbes and microbiology, Cell biology. Development of mathematical and computing knowledge and skills. Later - microbiology, biochemistry revisited aspects of enzymology food processing, food product development, food QA and safety and sensory evaluation.
Food Science: 6 courses	
Leeds - the only one that referred to Food Technology/Home Economics as an A level to be considered	Microbes, microbiology, food processing, food quality and safety, food product development, food quality and assurance and sensory analysis. All courses taught Nutrition plus cell biology, molecular biology, biochemistry/food chemistry, food production and sensory evaluation. Some taught food colloids, bioethics, food materials/ingredients, food and health and physiology.
Food and Nutrition: 18 courses	
Entry with science subjects – some naming the subject others only requiring ‘science’. Four universities named Food/Technology/Home Economics as acceptable Leeds: (Nutrition) ‘considered’ Nottingham: (Nutrition) an acceptable science subject. Newcastle (Food and Human Nutrition) considered in place of biology Coventry: (Food and Nutrition) Food Technology acceptable University of Ulster: Home Economics acceptable as a science.	A high level of commonality: all taught some aspects of microbiology, cell biology or molecular biology. Biochemistry and chemistry (7). 12 taught physiology (12) and endocrinology (3); nutrition and health (11), clinical nutrition (3), applied nutrition (2), diet therapy/dietetics (2), sport and exercise nutrition (3), food safety/hygiene (7) psychology (5), consumer behaviour (3), nutrition/health (9), food product design/development (7), food processing(4), Food analysis/evaluation(3), food marketing (1), food issues(4). Single modules in food services and catering, food origins, food policy and eating disorders.

Table 1: Entry requirement and content of university food related courses

Food and Nutrition was the most popular course. There were some links between the A Level specification and the undergraduate degree courses, for example in Food Technology and Bioprocessing (Reading University): food processing, food product development, food quality assurance and safety and sensory evaluation. Similarly, in Food Science: aspects of microbiology, food processing and food quality and safety and Nutrition courses: food product development, nutrition and health, sensory evaluation. Seven courses included food safety and hygiene, food product design/development, four taught food processing and food issues and three food analysis/evaluation.

The study showed that there were differences amongst the A Level Food Technology specifications and that different courses may have been appropriate for pupils with different career aspirations such as *nutrition, food product development and food manufacturing*. However, it was clear that, the then, current A Level Food Technology courses alone were considered insufficient preparation for university. The subject is so vast that it cannot all be covered in one subject on the school timetable, but in combination with chemistry and/or biology (depending on the aspiration) the A Level in Food Technology should not be dismissed.

A level subjects taken by students before entry to food related undergraduate degree courses.

A questionnaire was completed In November 2014 by 77 Year 1 students, on the *BSc Food Science* (14); *BSc Food Science with Business* (10); *BSc Food Technology with Bioprocessing* (2); *BSc Nutrition and Food Science* (36) and *BSc Nutrition with Food Consumer Sciences*

(15) courses in the Department of Food and Nutritional Sciences at Reading University (Rutland & Owen-Jackson, 2014b). (Table 2).

What subjects did you study at schools?	BSc Food Science	BSc Food Science with Business	BSc Food Technology with Bioprocessing	BSc Nutrition and Food Science	BSc Nutrition with Food Consumer Sciences	Total
	14 students	10 students	2 students	36 students	15 students	77
Biology	9	6	2	28	12	57
Chemistry	10	7	1	18	5	41
Mathematics	8	5	1	14	4	32
Food Technology	3	3	1	8	4	19
Psychology	0	0	0	6	8	14
English	1	2	0	8	1	12
German	1	0	0	8	0	9
Business studies	1	0	1	4	2	8
French	1	0	0	3	2	6
PE	2	0	0	2	2	6
Geography	2	0	0		3	5
History		1	0	2	2	5
Economics	1	1	0	2	1	5
Home economics	1	1	0	2	0	4
Physics	2	2	0	0	0	4
BTec Applied Science	0	1	0	1		3
Sociology	0	0	0	1	1	2
Philosophy	0	1	0	0	0	1
Music	0	0	0	1	0	1
Art	0	0	0	0	1	1
Spanish	0	0	0	1	0	1
Photography	0	1	0	0	0	1
ICT	0	0	0	0	1	1

Table 2 A Level subjects studied before entry to Reading University.

The A levels subjects studied were mainly science, with for example:

- *Nutrition and Food Science* - 36 students: biology (28), chemistry (18) mathematics (8), food technology (8);
- *Nutrition with Food Consumer Sciences* - 15 students: biology (12), chemistry (5), mathematics (4) and food technology (4);
- *Food Science* - 14 students, biology (9), chemistry (10), mathematics (3) and food technology (3);
- *Food Science with Business* - 10 students: biology (2), chemistry (5), mathematics (4) and food technology (3);
- *Food Technology with Bioprocessing* - 2 students: biology (2), chemistry (1), mathematics (1) and food technology (1).

The range of other A Level courses taken was broad with the most popular being psychology, English and German. Biology (57) was the most popular A level subject taken by the students, followed by chemistry (41) and mathematics (32) and interestingly, food technology (19) was the fourth most popular. This was despite the lack of direct reference to food technology as an entry requirement (Rutland, Owen-Jackson 2014a). There was an acknowledgment by the admissions tutor that there was a need for some revisions in a new A Level Food Technology to make it more appropriate for the course content followed by undergraduates at Reading. However, the research indicated that an appropriate food related A Level food course would be acceptable alongside science subjects.

Reasons given for studying food related higher education courses (Table 3)

Undergraduate courses	BSc Food Science	BSc Food Science with Business	BSc Food Technology with Bioprocessing	BSc Nutrition and Food Science	Nutrition with Food Consumer Sciences	Total
	14 students	10 students	2 students	36 students	15 students	77
Why did you choose to study your course? Work in:						
Food industry	12	9	2	30	7	60
New product development	12	7	2	23	4	48
Food science	19	6	0	21	0	46
Nutrition & dietetics	3	0	0	29	12	54
Food technology & processing	6	4	2	3	0	15
Hospitality & catering industry	4	3	0	5	1	13
Consumer science	2	1	0	1	4	8
What do you hope to gain from your course? Learn more about:						
Food industry	13	9	2	28	11	63
New product development	12	8	2	22	9	53
Food science	11	6	0	26	4	47
Food technology	7	5	2	13	9	46
Nutrition	6	3	0	31	6	46
Consumer science	6	2	0	0	2	10
Cookery skills	3	3	0	2	0	8

Table 3: Reasons given for studying food related courses in higher education

The range of reasons given for studying food related courses were broad. They included working in the food industry (60) learning about new product development (48), food science (46), nutrition and dietetics (54), food technology and processing (15), hospitality and catering (13), consumer science (8). The students hoped to learn more about the food industry (63), new product development (53), food science (47), food technology (46), nutrition (46), consumer science (10) and, least of all, cookery skills (8).

Suggested content of a new Food A Level.

A new A Level food related examination, that could act as a pathway and progression to university courses and a range of employment in nutrition, dietetics, nursing, health related professions, teaching and the food industry, was drafted by the author in Autumn 2018. The aim was to explore the possible content of an examination for pupils aged 16-18 years in England. A major source of information was from the book 'The Science and Technology of Foods' (Proudlove, 2009). The proposed title for the new course was 'Food Science and Technology'. The content was divided into three sections: *Food Consumption, Food Production and Food Processing* (Table 4).

Food Consumption
The composition and nutrition of foods: water, carbohydrates, lipids (fats), proteins, minerals, vitamins, pigments, flavours, additives and fortified and functional foods.
Human dietary and health studies: types and functions of nutrients, digestion & absorption, nutritional product analysis, nutritional labelling
Consumer choice: connections between food constituents, diet and health to understand the variability and diversity of psychological behaviour, political, cultural and social issues, changing eating patterns, obesity, malnutrition, undernutrition, emerging trends, market research.
Influences of the food industry: impact on health of highly processed foods, ready meals, increasing use of fast-foods, advertising, promotion and marketing techniques
Food Production
National and global issues: population growth and food supplies: food sources (animal, plant, fungi; sustainability of foods, food miles, synthetic foods, biotechnology of foods, functional foods, organic foods, genetically engineered foods, modification); new food sources and technologies.

Environmental challenges: production of biofuels, growing demand for major food crops like wheat and rice, livestock health, production to deliver improved food security and farming sustainability, increase of factory farming, new agricultural technologies, impact of automation on food production.
Handling and preparation of food materials: storage of raw materials, cleaning, sorting, and grading, size reduction, and mixing, filtration and blanching, distribution and transportation of foods.
Preservation of foods to prolong shelf- life and prevent spoilage and contamination: microbiology (bacteria, moulds, yeasts, algae and viruses), food spoilage caused by yeasts, moulds, and bacteria; preserving foods (e.g. heat processes, chilling, freezing, canning, dehydration, UHT, irradiation, modified atmosphere packaging); food safety and hygiene (food hygiene, poisoning and cross contamination)
Food Processing
Ingredients and commodities: dairy products; meat; fish; poultry and eggs; fruit and vegetable; cereals and baked products (bread making, cakes, biscuits and pastry); beverages; chocolate and confectionary
Physical and chemical working properties of ingredients: colloidal structures/systems of foods (e.g. sols, gels, emulsions, foams); changes that take place during preparation and cooking (e.g. gelatinisation, coagulation, caramellisation, Maillard reaction, emulsification, fermentation, antioxidants); enzymatic changes in the production of bread, beer and wine); raising agents (yeast, chemical)
Preparation and cooking of food products: use of a range of processes and skills; choice and use of ingredients for desired characteristics (e.g. shortening); effects of heat on different foods; use of heat transfer (e.g. radiation, convection, conduction); food safety and hygiene; sensory properties of foods (flavour, odour; colour, texture and appearance)
Applied food science and technology: product design and development, manufacturing and processing, analysis, quality control and quality assurance, biotechnology and innovation in food product development.
Awareness of industrial practices: manufacturing processes (product specifications, food control and safety, quality control and quality assurance, risk assessment and HACCP), transportation of foods
Impact of new technologies: novel ingredients and processes, nanotechnology/packaging of foods.

Table 4: Suggested content of a new Food A Level devised Autumn 2018.

School teacher 11-18	55.22%
School teacher 11-16	11.94%
Sixth-form/College teacher 16-18	2.99%
Student teacher	16.42%
Head of D&T / Food department in a school or college	28.36%
School-Based teacher trainer	5.97%
PGCE/Education lecturer (teacher trainer)	2.99%
Other university lecturer (please note discipline in box below)	1.49%
Food Science/Technology professional (please note detail in box below)	2.99%
Other: BSc Nutrition student, nutritionist (2), technicians (2) , work in hospital, special education and hospital, Founder of the Food Teachers Centre	10.45%

Table 5: Categories and percentages of respondents.

Sixty seven people responded including: a majority (55.22% + 11.96% + 2.99% = 69.85%) of school teachers with an additional 28.36% with middle management positions in schools. The respondents were asked to comment on the content:

- Was it sufficient?
- Should it be reduced?
- Should content be added?

	Sufficient content	Reduce content	Add content
Food Consumption			
<i>The composition and nutrition of foods:</i>	89.47%	3.51%	7.08%
<i>Human dietary and health studies</i>	82.46%	1.75%	15.79%
<i>Consumer choice</i>	75.0%	7.14%	17.86%
<i>Influences of the food industry</i>	66.0%	3.57%	30.36%
Food Production			
<i>National and global issues: population growth and food supplies</i>	83.64%	3.64%	12.73%
<i>Environmental challenges</i>	72.73%	5.45%	21.82%

<i>Handling and preparation of food materials</i>	70.91%	23.64%	5.45%
<i>Preservation of foods to prolong shelf- life and prevent spoilage and contamination</i>	87.04%	3.70%	9.26%
Food Processing			
<i>Ingredients and commodities</i>	86.79%	3.77%	9.43%
<i>Physical and chemical working properties of ingredients</i>	85.19%	5.56%	9.26%
<i>Preparation and cooking of food products</i>	87.04%	1.85%	11.11%
<i>Applied food science and technology</i>	73.58%	22.64%	3.77%
<i>Awareness of industrial practices</i>	81.13%	16.98%	1.89%
<i>Impact of new technologies</i>	87.04%	7.41%	5.56%

Table 6: Summary of 67 responses to the questionnaire

Discussion

The results showed some differences of opinion regarding the content of the draft A level Food based examination. The highest responses for sufficient content were: the composition and nutrition of foods (89.47%); preparation and cooking food products (87.04%); preservation of food to prolong shelf-life and prevent spoilage and contamination (87.04%) and the impact of new technologies (87.04%). However, the influences of the food industry (66.0%) were the lowest. The handling and preparation of food materials (23.64%) scored the highest for reducing content. Influences of the food industry scored highest (30.36%) to add content, followed by environmental challenges (21.82%). A reduction of applied science and technology (87.04%) and awareness of industrial practices (16.98%) was significant, as it indicted a lack of understanding of the importance of food production outside the home environment and in the food industry.

The response to 'should there be an A Level Food Course' was 'Yes' (100%), which was encouraging. Suggestions for titles were very broad; key words included food; nutrition; science and technology followed by the less popular preparation; diet/health; the future; development; production; manufacture and industry and home economics.

The main focus of the paper has been on the need to develop a new A Level food course that would provide progression for pupils interested in food and wanting to continue their studies in higher education. A course, that could leading to future careers in nutrition, dietetics, nursing, health related professions, teaching and the food industry within an informed knowledge economy. The 'Food Education Learning Landscape' (FELL) Report on food education, has had considerable influence and is based on 'learning the basics of food, where it comes from, how to cook it and how it affects their bodies in food teaching in England' (Oliver, 2017, p.6). However, it focuses on whole school managerial procedures and approaches rather than actual food teaching in the school curriculum. Though many secondary schools offer the new GCSE, overall the numbers continuing to study food in the curriculum beyond Year 8, it is in decline. Also, 'teachers are concerned about the removal of an A level 'food' qualification in England and Wales, which negatively affects the status of food in schools and limits career prospects in this area' (Ballam, 2018, p.8).

Developing and re-introducing an A Level food course is crucial to provide a route for pupils interested in food and wanting an entry requirement to food related courses alongside science subjects. The lack of such a pathway is a lost opportunity. However, the research results indicate that a larger and broader perspective is need to take into account the specific needs for training in food related areas not addressed by courses at a similar level. There may be a need for options within the assessment e.g. a core and options for schools and students to choose to take into account the broad range of food courses. The foods we eat directly relate to the health of our communities and how it is produced has a direct influence on the future of

the planet. More clarity on course content and assessment procedures is needed and there is an urgent need to draw together a group of interested people, including teachers, university course tutors, examination boards and the DfE to explore the issues involved in such an enterprise.

References

Ballam, R. (2018) Editorial. Where next for food education? In: *The British Foundation Nutrition Bulletin* 43, pp.7-9. London: British Nutrition Foundation.

DES. (1990). *Technology in the National Curriculum*. London: HMSO.

DfEa, (2014). *Reforming GCSE and A Level subject content consultation*. London: Department for Education.

DfEb, (2014). *Design and Technology: Draft GCSE subject content*. London: Department for Education

DfE, (2015). *Food preparation and nutrition GCSE subject content*. London: Department of Education

Food & Drink Federation (fdf), (2019). *Economic contribution and growth opportunities*, p.2.

<https://www.fdf.org.uk/publicgeneral/FDF-GT-Exec-Summary.pdf>

Oliver, J. (2017). *Food Education Learning Landscapes (FELL)*. London: Jamie Oliver Food Foundation, AKO.

www.schoolfoodmatters.org/news/food-education-learning-landscape-report

Lawson, S. (2013). Does food fit in design and technology? In Owen-Jackson, G. (Ed) *Debates in Design and Technology Education*, pp. 101-114. Abingdon: Routledge

Proudlove, R. K. (2009). *The Science and Technology of Foods*. Hampshire: Forbes Publications

Rutland, M., & Owen-Jackson, G. (2014a). Food technology: an initial exploration into its educational purposes. In H. Middleton (Ed) *Technology Education: Learning for Life* (Vol. 2, pp. 62- 70). 8th Biennial International Conference on Technology Education Research, Sydney, Australia: Griffith University.

Rutland, M., & Owen-Jackson, G. (2014b). A Level subjects studied prior to entry, and reasons for studying food related undergraduate degree courses. Unpublished research. *Reading University: Department of Food and Nutritional Sciences*

The perceptions of self-assessment in basic education in craft, design and technology.

Sari Saarnilahti, Eila Lindfors



Sari Saarnilahti
University of Turku
Finland
sari.saarnilahti@kotka.fi



Eila Lindfors
University of Turku
Finland
Eila.Lindfors@utu.fi

ABSTRACT

This article examines the perceptions and occurrence of self-assessment of sixth and ninth grade, 12 and 16 years old students (N = 508) and the different ways that self-assessment was carried out during a holistic craft process. The study was conducted in the context of the Finnish comprehensive education Basic Education curricula of 2004 and 2014.

The goal of self-assessment is to develop students' learning process. Self-assessment is an integral part of a holistic design and making process in craft, design and technology (CDT) education. Self-assessment can be implemented through evidence based, reinforcing, reflective and pragmatic self-assessment. Self-assessment is a part of design, planning and manufacturing a product. It can occur in every step of the process, also as the final assessment of the work.

The data was collected in town schools in comprehensive primary and secondary education in Finland in 2017. The summation-based analysis showed that there were statistically significant differences between student groups. The ninth grade students who did not study CDT as an optional subject expressed the most negative perceptions in all areas of self-assessment. Getting used to self-assessment was clearly associated with the students' positive perceptions towards self-assessment as a part of a learning process. The data from open-ended questions were in line with the result of the analysis.

Although the data of the study was collected in a geographically limited area, it gives an idea how students see self-assessment as a part of their learning. The results suggest the importance for students to acquire self-assessment skills not only as an important stage of their learning process but also from the positive learning experience point of view.

Key words: self-assessment, Craft, design and technology education, primary and secondary education, holistic craft process

Introduction

Self-assessment is a part of a holistic craft process. Self-assessment in a holistic craft process has been found to be linked to students' positive or negative attitudes towards self-assessment in general (Saarnilahti, Lindfors & Iiskala 2019). Craft, Design and Technology education (CDT) is a subject, that is taught to everybody in Finnish comprehensive education (grades 1-9, 7-16 years old students). A common subject continues to the end of the seventh grade. Furthermore, CDT can be chosen as an optional subject for grades eight and/ or nine. (Finnish National Agency for Education.)

Both self-assessment and intentional learning are strongly represented in the latest curricula of the Finnish comprehensive education (FNAE, 2014). Self-assessment together with an intentional craft process helps students to achieve their learning goals by offering a chance to reflect on their holistic craft process. Intentional learning can be understood as students' pursuit to understand the study goals in CDT (Vosniadou 2003).

The holistic craft process is divided into discrete stages including design, planning, manufacturing the product/solution and final assessment. The process is ongoing and the maker of the product can go back and forth to any step of the process at any given time (Lepistö 2004). Holistic craft process is also meant to educate students to understand the relations between these steps (Rönkkö 2011). Positive attitudes towards CDT enhances students' technical skills by deepening students' knowledge of the subject (Hilmola & Lindfors 2017).

Self-assessment is an important method of formative assessment. It gives students an opportunity to assess the quality of not only their work, but also their time management skills, goal setting and task performance. (Andrade & Valtcheva 2009.) Self-assessment differs from reflection. Self-assessment is anticipating and reflection is reactive. They both have a different purpose in a learning process. Reflection is used to find strengths and weaknesses of something that is already done. It can be directed to the work process, final product or students' planning skills for example. Self-assessment on the other hand aims to make a student a better learner and it is more flexible. Self-assessment can be done at any part of the process. (Desjarlais & Smith 2011; Burke, Lawrence, El-Sayed & Apple 2009.)

In this study self-assessment is divided into four different categories as follows: evidence based, reinforcing, reflective and pragmatic self-assessment (Shaw 1999; Kivipelto 2008). The decentralization of self-assessment into different categories helps to form a general overview of a target to be assessed (Clarke 2006). This model comes from evaluation practices in social work quality assessment, but it can also be linked to the Finnish curriculum of comprehensive education (FNAE, 2014) where aspects of evaluation are *learning*, *working* and *behaviour* (FNAE, 2014).

Evidence based self-evaluation links to intentional learning. It is relatively easy to see what works and what does not. Reaching to advance set learning target will be estimated after the work is completed. *Reinforcing* self-assessment brings out the student's successes and concentrates on the usefulness of the self-assessment in the context of learning. *Reflective* self-assessment focuses on what is learned, how good is the students' time management in part of the holistic craft process and what could be done differently. *Pragmatic* self-assessment is clearly the most formative assessment and it includes many of the students' choices for example choosing a work technique or finishing the product. (Shaw 1999; Kivipelto 2008; FNAE 2014.)

The purpose of this study was to clarify how students see self-assessment as a part of a holistic craft process. In this article, we focus on to deepen the results of the open-ended questions.

Method

The study utilized as a mixed method approach. It was important to use both qualitative and quantitative methods to answer the research questions profoundly. Mixed method can provide an overall picture of the issue at hand. (Johnson & Onwuegbuzie 2004; Johnson & Onwuegbuzie 2007.) In this article, we seek an answer to the research question: How do students consider self-assessment as part of their holistic craft process? Students' conceptions, attitudes and experience of self-assessment were studied. The result was examined also by gender.

An online inquiry was organized in May 2017 in a city of 54 000 inhabitants. Students (N=508) from sixth and ninth grade of comprehensive schools answered the survey anonymously. The inquiry was carried out during the school day in an electric learning environment. The teachers of each class gave the students instructions based on the researcher's forewords. Of the possible population of sixth and ninth grade students, 47,5 % took part to the inquiry. In the questionnaire, there were 35 Likert-scale questions, which were divided as follows: background variables, 4 variables that describe evidence based self-assessments, 4 variables for reinforcing self-assessments, 5 for reflective self-assessments and 5 for pragmatic self-assessments as well as open-ended questions. The questionnaire was based on the questionnaires of, Bland (2005) and Finnish National Agency of Education (Laitinen, Hilmola & Juntunen 2011; Hilmola 2011). In the preliminary testing of the questionnaire, problems were not perceived.

Sum variables, which were in accordance with the normal distribution, were formed in the analysis. The reliability coefficient of sum variables, the Cronbach's alpha was adequate in all the categories of self-assessment. The values were between 0,62 –0,90. A content analysis was used to inductively analyse the open-ended question data.

Results

For a statistical analysis, the sum variables were formed from different self-assessment categories (Table 1). The means of sum variables were between 2,92 –3,33 and standard deviations were 0,83 –0,88. Sum variables were normally distributed. According to the data the students had most experience in evidence based self-assessment and least in reflective self-assessment. Reinforcing and pragmatic self-assessment were in between these extremities. The results showed that the students from both sixth and ninth grade who were used to self-assessment in CDT were more open to the idea of self-assessment being a way to improve their learning, which was not the case with the ninth graders who did not study CDT as optional subject (Saarnilahti et al 2019).

Table 1: Sum variables mean and standard deviation in different categories of self-assessment (N=508). Likert scale 1= totally disagree – 5= totally agree.

Sum variables of different self-assessment categories	<i>Evidence based</i>	<i>Reinforcing</i>	<i>Reflective</i>	<i>Pragmatic</i>
M	3,33	3,19	2,92	3,14
SD	0,88	0,84	0,83	0,83

There were statistically significant differences between the girls and the boys only in two variables and the extremely significant difference in one variable. On these variables the averages were between 2,67 –3,47 and standard deviations were between 1,04 –1,28. Girl's attitude was more positive than boys' were. In the examination of all three variables the effect size however, remains small.

In the open-ended questions, students were asked what they think can be self-assessed in CDT, how often they self-assess their work and how and why the self-assessment is done. The students who understood the advantage and purpose of self-assessment better were more versatile in their answers than the students who react negatively to self-assessment. To some students (3%, n=15) the inquiry seemed insignificant and their answers were therefore scant.

Majority of students (85,5 %, n=434) were able to identify the different parts of the holistic craft process when asked what can be self-assessed in the craft process. Designing, planning, manufacturing the product and final assessment were all mentioned in the answers. Only 14,5 % of the students (n =74) could not mention any self-assessment targets in CDT.

More than fourth of the students (27 %, n=138) thought that self-assessment was useful. It also reflects to their work by improving their learning. Students felt that self-assessing gives them an opportunity to communicate with the teacher about their successes and failures in the holistic craft process. Students felt that they could appreciate their finished products and their own work better when they had self-assessed themselves.

“It is made so that the student would learn to estimate himself honestly and realistically so that the student would learn to appreciate the quality of their own work and to appreciate its skills which he has learned during the work.” (9th grade student)

To 53 % of the students (n=268) it seemed to be unclear for whom the self-assessment was done for. Some of the students thought, that self-assessment is made because of an external requirement, or that the self-assessment helps primarily the teacher to decide the grade for the student. Some of the students considered the self-assessment unnecessary and waste of time. Gladly self-assessment can also appear useful method of study one's own operations in learning.

“By doing self-assessment we learn to estimate our own learning. With self-assessment the student can see how he has succeeded and what there is still to learn.” (9th grade student)

The majority of students (90 %, n=451) could describe what self-assessment is and could name at least one method of how to do it. The answers indicated that schools carry out self-assessment in CDT in different ways. However, answers were given anonymously so

comparing the schools was not possible in this study. Some of the answers indicated that self-assessment is usually done at the end of every craft process, others seemed to be using self-assessment only at the end of the semester. Self-assessment tools also varied. Some students used only digital tools to self-asses and some used paper forms. However, in most cases the tools used for self-assessment varied.

“In the self-assessment, the student himself estimates his own working. The self-assessment can be made verbally, in writing, with the teacher's management, independently, and such like.” (9th grade student)

Of the students who participated in the inquiry, 15 % (n=76) indicated that they do self-assessment in CDT often. The one worrying fact is that 20 % (n=101) of the participants said they never did any self-assessment whatsoever.

Conclusion

According to the results self-assessment is mostly well received and practiced among students when they have had enough time and guidance to get used to it. Self-assessment helps students to understand the causal connection of the holistic craft process, the technological solutions and one's own operation as a learner. Students' accuracy of assessing themselves improves by practice (Guest & Riegler 2017). That is why teaching self-assessment to students must be considered carefully in planning a holistic craft processes and in teaching in general. Self-assessment must occur often and in many forms since the beginning of the school path. However, establishing the self-assessment practices is challenging, and attention should be paid to different ways to use self-assessment as an advantage. Self-assessment can be divided to smaller categories as we did in questionnaire to help students to understand the various phases of a holistic craft process.

The central result of the study is that the ninth grade students' conception of self-assessment was negative when they had not studied CDT as an optional subject in 8th or 9th grade. One could argue that CDT is one important context to teach self-assessment to all students in comprehensive education. Students who indicated that they have never done self-assessment are a worrying group for these skills are required in further education. The advantages of the self-assessment in learning are clear in higher education (Bland 2005; Brown et al 2015; Guest & Riegler 2017). Considering these students, one may ask whether all teachers teach and counsel students to use self-assessment by themselves. However, the significance of self-assessment emerges with the student's increasing ability to self-assess. The skill of self-assessment promotes learning and strengthens students' commitment to one's studies. (Hanrahan & Isaacs 2001; Keto 2015; Uusikylä & Mäkinen 2015; Lepistö 2004; Pöllänen & Kröger 2005; Ross 2006; Nicola & Macfarlane-Dick 2006.)

In a practical teaching situation, a teacher has to present students with the different phases of a holistic craft process. It is easier for a student to estimate one's own learning and operation if he/she understands the method and purpose of self-assessment. The significance of self-assessment for the student will become clear when the self-assessment methods are easy enough. With the careful design and planning of the product at the first phase of the process, it is simple to concentrate on thinking if the finished product meets the plan. When the principles of self-assessment are clear to students, they will understand the significance of it in supporting their own learning.

Despite that, the study was geographically carried out with a small sampling the results point out the fact that students' who are used to self-assessment will understand how self-assessment supports learning. Nearly half of the whole population in question answered to the inquiry. On this basis the results of the study can be considered quite representative in terms of the questionnaire survey. The results can therefore be generalized to a wider group and to other subjects. The next phase is to study how students' self-assessment shows in CDT from the teachers' point of view. Combining the findings of both studies, we can begin to build new self-assessment tools.

References

- Andrade, H. & Valtcheva, A. 2009. *Promoting Learning and Achievement Through Self-Assessment. Theory Into Practice*, 48(1), pp. 12–19. <https://www.tandfonline.com/doi/pdf/10.1080/00405840802577544?needAccess=true>
- Burke, K., Lawrence, B., El-Sayed, M., & Apple, D. 2009. *Process Education: Past, present, and future. International Journal of Process Education*, 1(1), pp. 35–42. http://www.processeducation.org/ijpe/pdf/pe_hxX.pdf
- Clarke, A. 2006. *Evidence-Based Evaluation in Different Professional Domains: Similarities, Differences and Challenges*. In: I.F. Shaw, J.C. Greene & M.M. Mark (eds.) *The SAGE Handbook of Evaluation*. <https://dx-doi-org.ezproxy.utu.fi/10.4135/9781848608078.n25>
- Desjarlais, M. & Smith, P. 2011. *A Comparative Analysis of Reflection and Self-Assessment. International Journal of Process Education*, 3(1), pp. 3–18. http://www.processeducation.org/ijpe/2011/proof_2011a.pdf
- Finnish National Agency for Education (25.3.2019) <https://www.oph.fi/english>
- Finnish National Agency for Education. 2014. *National core curricula for basic education* (in Finnish). http://www.oph.fi/download/163777_perusopetuksen_opetussuunnitelman_perusteet_2014.pdf
- Guest, J. & Riegler, R. 2017. *Learning by doing: Do economics studenta self-evaluation skills improve? International Review of Economics Education* 24 (2017), pp. 50–64.
- Hanrahan, S.J. & Isaacs, G. 2001. *Assessing Self- and Peer-assessment: the students' views. Higher Education Research & Development*, 20(1), pp. 53–70. https://pes.concordia.ca/docs/assessing_self.pdf
- Hilmola, A., & Lindfors, E. (2017). *Pupils' performance in managing the holistic craft process. Techne Serien - Forskning I Slöjdpedagogik Och Slöjdvvetenskap*, 24(1), pp. 29–41. <https://journals.hioa.no/index.php/techneA/article/view/1808>
- Johnson, R.B. & Onwuegbuzie, A.J. 2004. *Mixed Methods Research: A Research Paradigm Whose Time Has Come. Educational Researcher*, 33(7), pp. 14–26. <http://www.jstor.org/stable/3700093>
- Johnson, R.B., Onwuegbuzie, A.J. & Turner, L.A. 2007. *Toward a Definition of Mixed Methods Research. Journal of Mixed Methods Research*, 1(2), pp. 112–133. <http://mmr.sagepub.com/cgi/content/abstract/1/2/112>

Keto, U. 2015. Self-assessment as quality tool. In: M. Nykänen (eds.) Self-assessment as quality tool of the institute of higher education. Mikkeli: Mikkeli University of Applied Science MAMK, A: TUTKIMUKSIA JA RAPORTTEJA – RESEARCH REPORTS 102, pp. 10–16.

Kivipelto, M. 2008. *Engagin evaluation. Guidance to principles and practices*. Helsinki: Research centre of the health care and social services, STAKES.

Lepistö, J. 2004. *Sloyd as an educational tool. A follow-up study on students' conceptions of sloyd as an educational tool before and after a basic level course of sloyd in class teacher education*. (Doctoral thesis, University of Turku) Serie C: Part 219.

Nicola, D.J. & Macfarlane-Dick, D. 2006. *Formative assessment and selfregulated learning: a model and seven principles of good feedback practice*. *Studies in Higher Education* 31(2), pp. 199–218.

https://www.researchgate.net/profile/David_Nicol/publication/228621906_Formative_Assessment_and_Self-Regulated_Learning_A_Model_and_Seven_Principles_of_Good_Feedback_Practice/links/561bcc9808aea80367242f55.pdf

Pöllänen, S. & Kröger, T. 2005. *Perspective to the holistic craft process*. In: J. Enkenberg, E. Savolainen & P. Väisänen (eds.) *Examining teacher training –skilful teacher*. University of Joensuu: Department of Teacher Education Savonlinna campus, pp. 160–172.

Ross, J.A. 2006. *The Reliability, Validity, and Utility of Self-Assessment*. *Practical Assessment, Research & Evaluation*, 11(10), pp. 1–13. <http://pareonline.net/getvn.asp?v=11&n=10>

Rönkkö, M-L. 2011. *Craft has many meanings. The meanings of craft perceived by the students in teacher education and how they are taken into account in craft teaching* (Doctoral thesis, University of Turku) Serie C: Part 317.

Saarnilahti, S., Lindfors, E. & Iiskala, T. 2019. *The perceptions of self-assessment in basic education in craft, design and technology - Pupils' views* In: M. Rautiainen & M. Tarnanen (eds.) *From study into classrooms*. Subject Didactical research serie, pp. 445– 464. <https://helda.helsinki.fi/handle/10138/298542>

Shaw, I. 1999. *Evaluate your own work. Guide of the reflective and authorising evaluation*. Helsinki: Research centre of the health care and social services, STAKES. [translated by L.Yliruka] Original text: Shaw, I. 1997. *Be Your Own Evaluator. A Guide to Reflective and Enabling Evaluation*. Prospect Training Publication.

Uusikylä, P. & Mäkinen, A-K. 2015. Realize – assess – improve: Self-assessment as tool of the developing of ESR projects. Ministry of Economic Affairs and Employment of Finland. http://www.rakennerahastot.fi/vanhat_sivut/rakennerahastot/tiedostot/esr_julkaisut_2000_2006/esitteet_ja_oppaat/oppaat/02_itsearviointiopas.pdf

Vosniadou, S. 2003. *Exploring the Relationships between Conceptual Change and Intentional Learning*.

https://www.researchgate.net/profile/Stella_Vosniadou/publication/251736849_Exploring_the_Relationships_between_Conceptual_Change_and_Intentional_Learning/links/53edc01f0cf2981ada170075/Exploring-the-Relationships-between-Conceptual-Change-and-Intentional-Learning.pdf

Exploring the nature of young learners' convergent thinking during designing.

Alice Schut, Nicolaas Blom



Alice Schut
Delft University of Technology
Netherlands
a.schut@tudelft.nl



Nicolaas Blom
University of Pretoria
South Africa
nicolaas.blom@up.ac.za

ABSTRACT

During designing, learners use a combination of divergent and convergent thoughts to achieve design synthesis. Although much has been written on the nature of divergent thinking during designing and ways to facilitate the generation of thoughts and ideas, limited research has been conducted on the nature of learners' convergent thinking during designing. The purpose of this study was therefore to explore the nature of young learners' convergent thinking during different design situations. In this paper we report on two different cases in which we could observe learners' potential for convergent thinking. The results indicate that children do not 'naturally' engage in convergent thinking while designing. Even when using convergent feedback students did not effectively engage in convergent thinking. Although the effectiveness of design cognition depends on the ability to proficiently engage in convergent thinking, future research is needed to understand how teachers can effectively facilitate these processes with tools and techniques.

Keywords: Convergent thinking, Design cognition, Design feedback, Design processes

INTRODUCTION

In recent years, cognitive psychology has made significant progress in understanding the nature of thinking involved during designing (Goldschmidt, 2016; Pringle & Snowden, 2017). It is generally understood that designers use both divergent and convergent thinking during their creative problem solving endeavours (Goldschmidt, 2016; Guilford, 1967; Howard-Jones, 2002). Divergent thinking is generative in nature and is necessary to produce a wide range of new thoughts and ideas (Goldschmidt, 2016; Guilford, 1967; Howard-Jones, 2002), while convergent thinking is reflective in nature and involves the ability evaluate, develop and bring together generated thoughts with the purpose of solving a problem (Goldschmidt, 2016; Guilford, 1967; Howard-Jones, 2002).

In the past, design researchers have placed much emphasis on divergent thinking during

designing, as it has been viewed as the backbone of creativity (Ward, Smith, & Finke, 1999). In fact, the majority of developed psychometric testing instruments involved in studying creative behaviour is centred on divergent thinking (Runco & Acar, 2012). However, it is now widely acknowledged that designing requires continual shifts between divergent and convergent thinking (Goldschmidt, 2016; Pringle & Snowden, 2017), but the nature of convergent thinking has been a neglected area of study in the literature (Goldschmidt, 2016; Runco & Acar, 2012; Cropley, 2006)

This study aimed to explore the nature of learners' convergent thinking from microscopic and macroscopic perspectives to provide insight into the ways that learners naturally engaged in unguided, and minimally guided design processes. To this end, our research was guided by the following research question: *What is the nature of learners' convergent thinking during the design process?* If convergent modes of thinking are integral to learners' successful design processes, we believe that it is necessary for teachers to understand the nature of convergent thinking, to identify opportunities for convergent thinking and to be able to facilitate it with effective tools and techniques.

THEORETICAL FRAMEWORK

For the study of learners' convergent thinking, we adopted a combination of dual-process theories of creative cognition (Howard-Jones, 2002; Sowden, Pringle, & Gabora, 2015). The underlying assumption of these theories is that creative cognition involves the shifting between two modes of thinking. From this point of view, modes of thinking are conceptualised as varying on a continuum from generative (divergent) to evaluative (convergent) thinking (Howard-Jones, 2002; Sowden et al., 2015). From a design cognition perspective, designers shift between a generative mode of thinking which supports the generation of new thoughts and ideas; and an evaluative mode of thinking conducive to reflection and evaluation of previously generated thoughts (Sowden et al., 2015). For this paper we only discuss moments where learners engaged in convergent modes of thinking.

METHODOLOGY

In order to investigate the nature of young learners' convergent thinking processes, the authors combined data sets that were collected in two different investigations. Although the nature of learners' convergent thinking was not the initial intention of these investigations, it nevertheless afforded secondary data analysis.

Case 1, a microscopic perspective

The first case involves the study of three teams, each comprising three purposefully selected Grade 8 learners between the ages of 14-15, situated in three different medium-resourced classrooms in South Africa. These learners had some experience in designing, as they have been involved in technology education for at least a year. Data for this case was collected by means of a Think Aloud Protocol Study (TAPS) in which concurrent qualitative and quantitative data were generated (Creswell & Plano Clark, 2018). Conducting a TAPS allowed us to microscopically study the development of learners' convergent thinking while they were engaged in a given 1-hour design task, without the aid of a teacher or instruction. The given design task entailed the design of a recyclable heat retaining food container to be used at a taxi depot in an informal settlement in South Africa. The generated data were subsequently analysed by means of linkography (Blom & Bogaers, 2018; Goldschmidt, 2014) in order to establish critical design moves indicative of convergent thinking during their design processes.

Case 2, a macroscopic perspective

The second case study involved one classroom in a primary school situated in the Netherlands. This classroom consisted of 24 learners between the ages of 9-11, which were purposefully divided into six gender-mixed design teams of four by the teacher. They had not participated in any design project prior to this one. The study took place over a period of seven weeks, which culminated in seven design sessions of 90 to 120 minutes. Three facilitators were present during the sessions to guide the teams. In order to elicit the learners' design thinking, design teams were presented with a design task by a real-life client. The design task instructed the learners to 'design a game, lesson or sport equipment for the gymnasium of the future that would enable children with different participation motives to be physically active together'. For this case, we focused on the 4th and 7th design session, in which design feedback was given on the ideas generated by the design teams. The feedback sessions were facilitated in a classroom setting in which all the design teams, the client and facilitators were present. Each design team took turns to present their design idea to the client and the other design teams (their peers). After presenting, each team received feedback from the client and their peers on the status of their design idea. For both design feedback moments, the client and peers received no specific instruction from the facilitators on how to give feedback. It was expected that the teams would use the design feedback that was given to improve their design idea. This expectation was communicated to the teams by the client through a short presentation at the start of 4th design session, with as a core message: 'Feedback = ok!'.

Data was collected by means of audio and video recordings, while material produced by the learners were photographed. During the data analysis we were particularly interested in the divergent or convergent nature of the feedback provided by the client and the peers and the reactions of the design teams to this feedback. Segments were created of consecutive feedback and responses following the same topic and within these segments pairs of feedback and response were formed. To determine the nature of the feedback, Eris's question-driven design model was used as coding scheme (Eris, 2004). Feedback which was not comprised of questions were coded inductively, which resulted in three new codes: 'Critique', 'Compliment' and 'Direct recommendation'. For the purpose of this study, we added these three codes to Eris' model and classified them as Low-level Comments and part of the *convergent* category. This adapted model is visualized in figure 1. The responses to the feedback were labelled through open-coding. Afterwards we refined these codes by comparing them to a framework of student response codes created by Cardella et al. (2014) and Cummings et al. (2015).

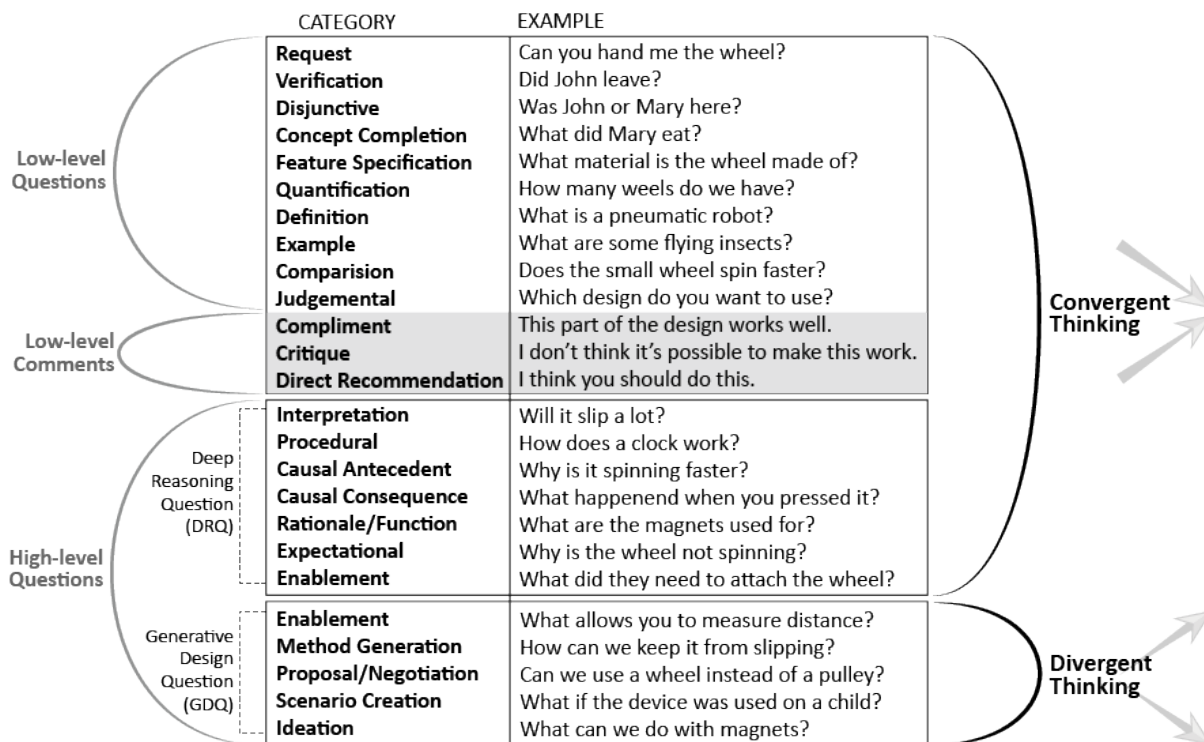


Figure 1: Eris' Question Driven Design Model. For the purpose of this study the low-level comments category was added to the model.

RESULTS AND DISCUSSION

Case 1: convergent thinking during critical moves

To study how learners' convergent thoughts were instantiated, we analysed each design process using linkography. In this study, we only focused on critical forward and critical backward design moves. For more information on how Linkography can be used to analyse learners' design processes, see Blom and Bogaers (2018).

Critical forward design moves are design moves in a linkograph that have a high number of links to future generated design moves. The links in critical forward design moves demonstrate instances where the learners' propose or generate new thoughts or design ideas and are indicative of learners' divergent thinking (Goldschmidt, 2016). Critical backward design moves are moves that have a significant high number of links to previously generated design moves. The links in these moves show where the learners evaluate, develop or reflect on previously generated thoughts and are indicative of learners' convergent thinking processes (Goldschmidt, 2016). In order to determine each group's critical design moves we identified the 10-12% moves with the highest number of forward and backward links of the total number of moves, as suggested by Goldschmidt (2014).

Table 1: Ratio of critical moves between the groups

	Number of CMs	%CM>	%CM<
Group A	31	84	16
Group B	18	72	28
Group C	25	88	12

In Table 1, each group of participants generated different number of critical forward (CM \rightarrow) and critical backward (CM \leftarrow) design moves. When looking at the ratio of \leftarrow CM to CM \rightarrow generated, it comes close to 80:20 for Groups A and C; and 70:30 for Group B. According to Goldschmidt (2016), these ratios are not consistent with most studies on professional designers, which usually have a ratio 60:40. This implies that the participants were able to generate new emerging thoughts that were critical in the development of future design moves, but they had difficulty to generate thoughts that were critical in exploring or summarising previously generated thoughts. This finding is also consistent with previous studies on professional designers and learners' design cognition which found that both novice and expert designers focus on generative thinking at the expense of evaluative thinking (Mentzer, 2014; Stempfle & Badke-Schaub, 2002; Welch, 1996). Figures 2, 3 and 4 illustrates the emergence of critical backward and critical forward moves during each group of participants' design processes.

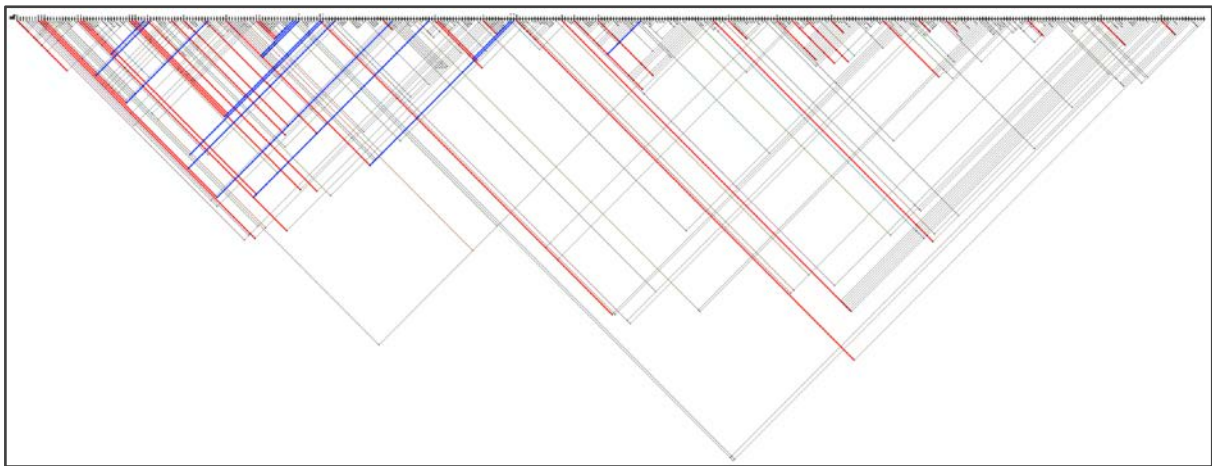


Figure 2: Group A's linkograph indicating critical forward moves (red) and critical backward moves (blue)

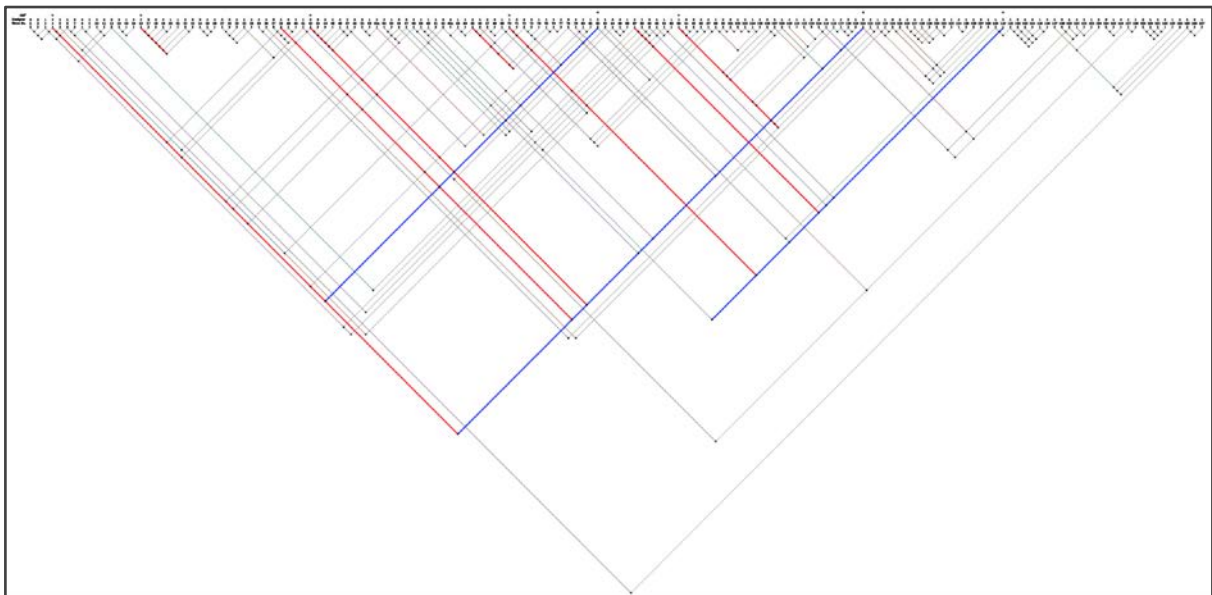


Figure 3: Group B's linkograph indicating critical forward moves (red) and critical backward moves (blue)

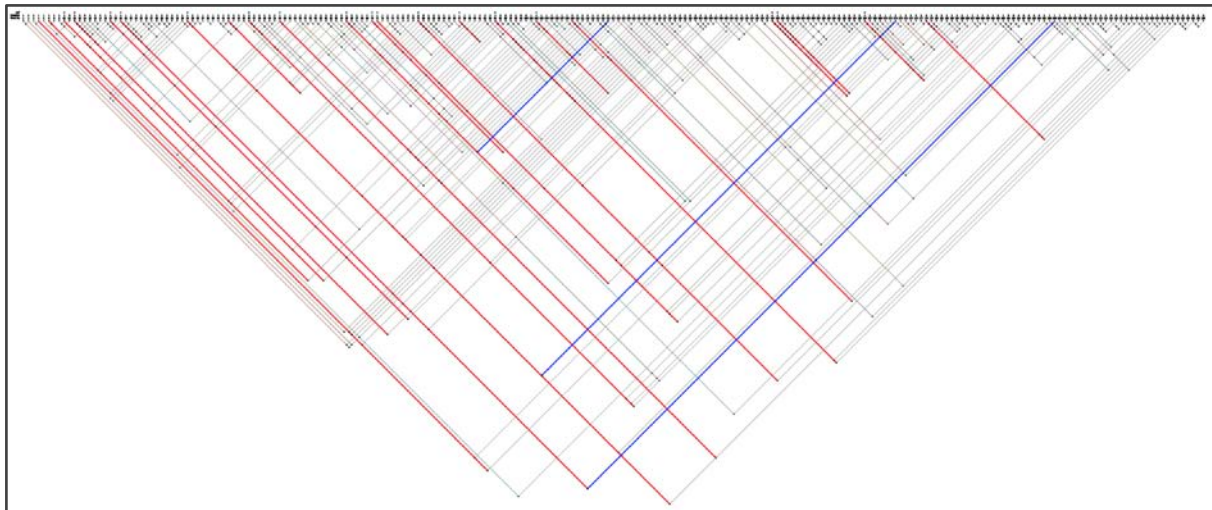


Figure 4: Group C's linkograph indicating critical forward moves (red) and critical backward moves (blue)

The figures support Table 1 by illustrating the limited critical backward design moves (blue) that were generated in comparison with critical forward design moves (red) in each group. Additionally, the figures also show the distribution of the critical moves within each group's design process. In Figure 2, Group A's linkograph shows that the majority of their critical backward moves were generated in the first half of their process, indicating that they made critical decisions early in their process, but they did not necessarily engage in evaluative or reflective thought during the second half of their process. This means that Group A committed to their chosen design solutions early in their design process, and did not refine or develop these solutions significantly during the later stages of designing. In Figure 3 and Figure 4 Group B and C generated their critical backward design moves toward the middle and end of their design process, indicating that Groups B and C only made design commitments during the later stages of their design processes. However, based on the limited number of critical backward design moves, Groups B and C also did not engage in sufficient reflective and evaluative processes to refine or develop their design ideas.

One reason for the learners' lack of engagement in convergent thinking might be due to the lack of pedagogical support in the learning environment. To this end, we further investigated the nature of learner's convergent thinking during design feedback sessions, as these sessions provide learners with opportunities to reflect on, evaluate and revise their design ideas through convergent thinking (Oh et al., 2013).

Case 2: Feedback and responses

In order to investigate learners' convergent thinking during design feedback sessions, we investigated the dialogues between the design teams, the design client, and the peers. Based on our study of the design feedback, we found that both the client and the peers were able to give both divergent (DT) and convergent (CT) feedback to the design teams, shown in Figure 5. Upon closer examination we saw that the majority of the given feedback was convergent in nature. Convergent feedback was visible when the clients and peers posed low-level questions and comments or high-level Deep Reasoning Questions (DRQs) to the design teams. The client's convergent feedback consisted mainly of low-level questions and comments. The low-level questions were generally posed to clarify or verify certain aspects of the design idea and the low-level comments consisted mainly of compliments. The peers' convergent feedback were predominantly high level DRQs. DRQs generally ask for reflection and evaluation of the design idea, which can ultimately help to develop and improve it. Through these questions the peers often revealed to the design teams how they expected

certain mechanisms in the design idea to function incorrectly, or how their design ideas did not yet adhere to the initial design criteria.

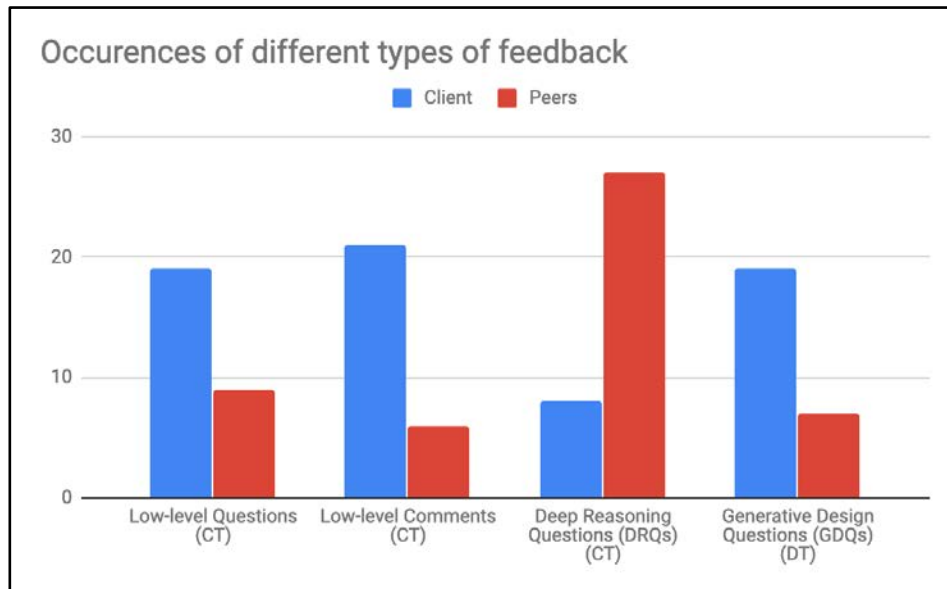


Figure 5: Occurrence of the different types of feedback posed by the client and peers in the feedback sessions.

In terms of the design teams' responses to the given feedback, we found that the learners did not engage in convergent responses. Instead, we noted that the design teams often responded in a defensive or uncritical manner to the convergent feedback. We characterised this behaviour in four response types, namely, 'band-aids', 'already in there', 'question not relevant', and 'it's not possible' (Schut et al., submitted). These four response types led us to see that the design teams' often rejected or ignored the given feedback. This implied that the design teams' ideas did not undergo development as most of the core characteristics of their design ideas remained intact and unchanged (Schut et al., submitted).

Although design feedback has the ability to encourage designers to take DT as well as CT paths during their design process (Cardoso et al. 2014; Yilmaz and Daly 2014, 2016), our results show that convergent questions or comments did not necessarily guarantee learners' responding in a convergent manner. Despite the fact that most feedback was convergent in nature, it resulted in limited convergent design responses. This implies that the design teams did not use the given feedback to reflect on and evaluate on their design ideas. Instead, they appeared to be fixated on the current state of their design.

CONCLUSION

Although it is widely acknowledged that during designing learners should engage in a combination of divergent and convergent thinking processes, limited empirical research have revealed how learners engage in these thought processes. For this study we focused on the nature of learners' convergent thinking processes through both microscopic and macroscopic lenses. By combining different samples and data analysis perspectives a preliminary understanding have started to emerge. Our first case showed that learners engage in limited convergent thinking in an unguided environment. In the second case we demonstrated that even when provided with convergent feedback, learners tend to respond by rejecting or ignoring the feedback. There may be various reasons underlying this, including, learners' limited experiences or training in convergent thinking, learners' inexperience in dealing with convergent feedback, or the teachers' and clients' limited training in giving appropriate

feedback. However, it still remains unclear as to how learners can be facilitated to effectively engage in convergent thinking. As such, further research is needed to establish how convergent thinking processes could be effectively taught and facilitated in the classroom, by means of appropriate feedback or effective design tools.

REFERENCES

- Blom, N. W., & Bogaers, A. (2018). Using Linkography to investigate students' thinking and information use during a STEM task. *International Journal of Technology and Design Education*, 1–20. <http://doi.org/https://doi-org.uplib.idm.oclc.org/10.1007/s10798-018-9489-5>
- Cardella, M. E., Buzzanell, P. M., Cummings, A., Tolbert, D., & Zoltowski, C. B. (2014). A Tale of Two Design Contexts : Quantitative and Qualitative Explorations of Student-Instructor Interactions Amidst Ambiguity. In *DTRS 10: Design Thinking Research Symposium*.
- Cardoso, C., Eris, O., Badke-schaub, P., & Aurisicchio, M. (2014). Question asking in design reviews: how does inquiry facilitate the learning interaction? In *Design Thinking Research Symposium* (pp. 1–18).
- Creswell, J. W., & Plano Clark, V. (2018). *Designing and Conducting Mixed Methods research* (Third). Thousand Oaks, CA: SAGE Publications.
- Cropley, A. (2006). In Praise of Convergent Thinking. *Creativity Research Journal*, 18(3), 391–404.
- Cummings, A., Tolbert, D., Zoltowski, C. B., Cardella, M. E., & Buzzanell, P. M. (2015). A Quantitative Exploration of Student-Instructor Interactions Amidst Ambiguity. In R. S. Adams & J. A. Siddiqui (Eds.), *Analyzing Design Review Conversations* (pp. 395–412). West Lafayette, Indiana: Purdue University Press.
- Eris, O. (2004). *Effective Inquiry for Innovative Engineering Design*. Boston: Kluwer Academic Publishers.
- Goldschmidt, G. (2014). *Linkography: Unfolding the design process*. Cambridge MA: MIT Press.
- Goldschmidt, G. (2016). Linkographic Evidence for Concurrent Divergent and Convergent Thinking in Creative Design. *Creativity Research Journal*, 28(2), 115–122. <http://doi.org/10.1080/10400419.2016.1162497>
- Guilford, J. P. (1967). *The nature of human intelligence*. New York, NY: McGrawHill.
- Howard-Jones, P. A. (2002). A dual-state model of creative cognition for supporting strategies that foster creativity in the classroom. *International Journal of Technology and Design Education*, 12(3), 215–226. <http://doi.org/10.1023/A:1020243429353>
- Mentzer, N. (2014). Team Based Engineering Design Thinking. *Journal of Technology Education*, 25(2), 52–72.
- Oh, Y., Ishizaki, S., Gross, M. D., & Yi-Luen Do, E. (2013). A theoretical framework of design critiquing in architecture studios. *Design Studies*, 34(3), 302–325.
- Pringle, A., & Snowden, P. (2017). Unearthing the creative thinking process: Fresh Insights From a Think-Aloud Study of Garden Design. *Psychology of Aesthetics, Creativity, and the Arts*, 11(3), 344–358. <http://doi.org/http://dx.doi.org/10.1037/aca0000144>
- Runco, M. A., & Acar, S. (2012). Divergent Thinking as an Indicator of Creative Potential. *Creativity Research Journal*, 24(1), 66–75. <http://doi.org/10.1080/10400419.2012.652929>
- Schut, A., Klapwijk, R., Gielen, M., Van Doorn, F., & De Vries, M. J. (submitted). Uncovering Early Indicators of Fixation in the Later Stages of Children's Design Processes. *International Journal of Technology and Design Education*.
- Sowden, P. T., Pringle, A., & Gabora, L. (2015). The shifting sands of creative thinking: Connections to dual-process theory. *Thinking and Reasoning*, 21(1), 40–60.
- Stempfle, J., & Badke-Schaub, P. (2002). Thinking in design teams - An analysis of team communication. *Design Studies*, 23(5), 473–496. <http://doi.org/10.1016/S0142->

694X(02)00004-2

- Ward, T. B., Smith, S., & Finke, R. A. (1999). Creative cognition - theory, research, and application. In R. J. Sternberg (Ed.), *Handbook of Creativity* (pp. 190–212). Cambridge MA: MIT Press.
- Welch, M. (1996). *The strategies used by ten Grade 7 students working in single-sex dyads to solve a technological problem*. McGill University.
- Yilmaz, S., & Daly, S. R. (2014). Influences of feedback interventions on student concept generation and development practices. *Design Thinking Research Symposium*, (1992), 1–25.
- Yilmaz, S., & Daly, S. R. (2016). Feedback in concept development: Comparing design disciplines. *Design Studies*, 45, 137–158.

Introducing Middle School children to compulsory D&T: Does It Influence Their Choice of Subject Later On? A Case Study of Maltese State Secondary Schools.

Marilyn Stellini, Sarah Pulé



Marilyn Stellini
St Aloysius College
Malta
marilyn.stellini.07@gmail.com



Sarah Pulé
University of Malta
Malta
sarah.pule@um.edu.mt

ABSTRACT

In 2005, Design and Technology (D&T) was introduced in Maltese Secondary schools and it has been offered as an optional subject till the present situation. In 2014, D&T has been introduced as a compulsory subject during the first and second year of middle secondary schools yet there was no study indicating its' impact on student's perception linked to gender. Issues have surged where low gender representation from females were noticed within schools. Diekman, Weisgram, and Belanger (2015) argue that women in STEM fields of occupation are generally underrepresented, D&T included. Sonja Niiranen (2018), states that despite the work developed on gender equality, technology education appears to have issues related to gender. The number of women in technical careers in EU countries has not increased. This might be due to how childhood experiences set future interactions within technology education. This research investigates the relationship between students' perceptions of D&T with respect to gender during their compulsory exposure to the subject in Maltese middle schools. Questionnaires were used to build a quantitative case study for exploring the criteria used by students to decide whether to opt for or drop D&T after middle school. Results indicate that students' perception concerning D&T is generally positive for both genders and the female population has progressively increased, although it is still considered low. The students enjoy D&T in class and value it as a life enhancing subject however, they do not wish to continue studying it further than middle school. Results also indicate that exposure at school had minimal effect on students' decisions to continue their studies in D&T. The prime variables influencing and ultimately driving students' decisions seem to be sociocultural factors and future career aspirations. The research concludes that the creation of future employments for D&T graduates and the recognition of D&T courses and qualifications by employers will probably be the most influential factor governing the uptake of the study of D&T at the level of secondary school.

Keywords: Design and Technology, gender, subject choice, career aspiration

INTRODUCTION

The development of Design and Technology, D&T as a subject in Maltese Secondary schools, has been subject to debate for the past fourteen years. The subject is facing different challenges provoked by how it has been introduced in the Maltese Secondary schools (Navarro & Pulé, 2015). Trade schools in Malta, back to 1972 were labelled for disobedient and low-achieving students, such that it has contributed to a negative perception of D&T (Sultana, 1995). Purchase (2005) argues that having been introduced in 2005 as an optional subject, it is a relatively new subject within the Maltese Educational system and society. In 2012, D&T has been introduced as compulsory subject in all State Secondary Middle schools. During these two years students gain ground knowledge in Resistant materials, Electronics and Graphical Communication. At the end of the scholastic year in Form2/ Year 8 students are offered the option of choosing D&T as an optional subject through their senior secondary years.

The following research questions were central to the study:

1. Does compulsory introduction to D&T at middle school influence choice of subject later on?
2. Are there issues of gender stereotype patterns in how student base their decision regarding choosing or dropping the subject?

LITERATURE REVIEW

The European Commission of 2013 identified gender as a socio-cultural factor that shapes behaviours and attitudes (European Commission, 2013). It explains how both gender behaviour and attitudes are learned and not fixed. Gender norms are constantly in flux. Stets and Burke (2000) argue how members of society decide how male and female roles are defined. Males are associated with masculinity while females are associated with femininity. Technology education is usually perceived as a masculine discipline and it is deemed as an essential part of the upbringing and connection to masculinity from early socialization (Holth & Mellström, 2019). Salminen-Karlsson (2007) states that girls are not interested as much as boys in technology as they do not acquire the same experiences during early childhood. As they grow up, boys experience technology as their domain and usually leave girls out from technical activities and discussions. Such consequences attribute technology to masculinity and isolate girls from the subject (Salminen-Karlsson, 2007).

Van der Vleuten, Jaspers, Maas and Van der Lippe (2016) argue how gender ideology can imply on educational choices by influencing three main factors. It effects how students evaluate their competence within the subject, what occupational values are perceived as important for future occupation and their preferred current subject in school. Gender ideology shapes boys' occupational and subject preferences while contrary for girls, it shapes their competence beliefs. This shows that the more students have internalized traditional gender ideology, the more they shall make educational choices respective to masculine and feminine

norms (Van der Vleuten, Jaspers, Maas, & Van der Lippe, 2016). Stereotypes of what is masculine and feminine are pervasive throughout society and impact beliefs about ones' strength and shortcomings. Wang and Degol (2017) state that it is ideal to maximize career options for women and emphasize the ideal of hard work and talent. This would act to remove masculine stereotypes and misinformation of STEM and STEM careers.

Gender in Design and Technology

As described in the Maltese D&T curriculum of 2015, the subject is multidisciplinary with constantly changing academic disciplines (Education, 2015). Opportunities for students are given where they can cultivate creative problem-solving skills which are essential to the 21st century education (Education, 2015). Bell, Hughes, & Owen-Jackson (2013), mention how researchers (Kimbell et. al. 1991; Murphy, 2006) found how in D&T tasks, both genders have different ways how to respond and work. Boys favour tasks which are short with instant reward style whereas girls tend to take longer and prefer to develop planning while refining work. Although both have different approaches the department for education and skills in UK (2007), published data stating girls do better than boys in D&T even among subject areas widespread with boys.

Jan Harding (2002) argues how girls perform with confidence and have the capability of completing reflective tasks such as identifying a need or evaluation of the project in D&T. However, looking at the technical aspect, Harding reports that girls had low performance in making use of tools. Further, Webber and Custer (2005), identified how girls prefer designing rather than utilizing. This is consonant with the results found by the APU, showing that girls do not feel confident in making use of tools and machines (Kimbell, Stables, & Green, 1996; Kimbell R. A., 1991). Contrary to girls, in terms of boys' performance during D&T, Harding (1997) states how boys focus more on right or wrong answers. Boys are better able than girls to master capability aspects when they are engaged in development of solutions (Spendlove, 2002).

STEM, Gender Research and Influential Factors

Girls are underrepresented in science, engineering, technology and mathematics (STEM) (Gjersoe, 2018). Women not opting for STEM studies and careers provoke questions of whether these are influenced from innate talents or sociocultural factors within society. Pisa study in 2015 found little difference between gender performance across Organisation for Economic Co-operation and Development (OECD) countries. This indicates that difference in performance by gender does not stem from innate talents but rather from influential factors such as parents, teachers, policies and politics (Gurría, 2018). Sociocultural factors may also be the reason why women are not equally represented in certain occupations (Darmanin, 1992). It could also be a reason that has shaped the number of students opting to choose D&T in Malta in these last years.

The influence can arise from different issues such as background of education and occupations of parents/guardians. Tyler & Osborne (2012) state that the inheritance of cultural capital has restrictions upon the student's pathways as parents/guardians and family can impose issues where support is not granted to them in pursuing academic studies in STEM subjects. There is also a strong belief that students who opt for a subject in science, engineering and technology are partially influenced by the teachers in different ways. Motivation seems to be one factor (Faitar & Faitar, 2013).

METHODOLOGY

This study is based on 271 questionnaires distributed among students at Forms 1 and 2/ Year 7 and 8, at the age of 11 to 13 years old. To reach the desired response rate of 250 questionnaires, 300 questionnaires were distributed between three middle schools having different catchment areas. The sample size of 271 participants provides a margin of error of 5.58% (assuming 95% confidence interval). The sample consists of 51.7% females and 48.3% males, indicating that more females participated in this study

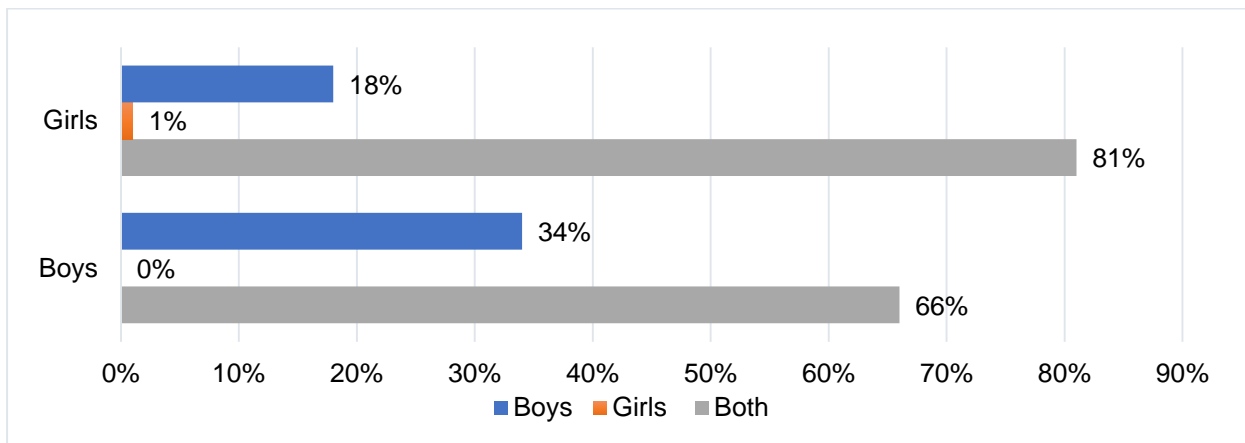
In this research, thematic analysis was applied; concepts were broken into various components that could be collected through the questions provided, producing quantifiable data. Fixed-choice questions were chosen as these are relatively easier to complete keeping in mind these were to be administered with eleven to thirteen-year-old adolescent students (Schutt, 2012, p. 257). When the data was examined, core themes were extracted such that coding could take place in relation to these themes (Bryman, 2008). Non-parametric test, Mann Whitney U test was used to compare between independent groups making use of Statistical Package for the Social Sciences, SPSS.

RESULTS

Design and Technology applies for both Gender

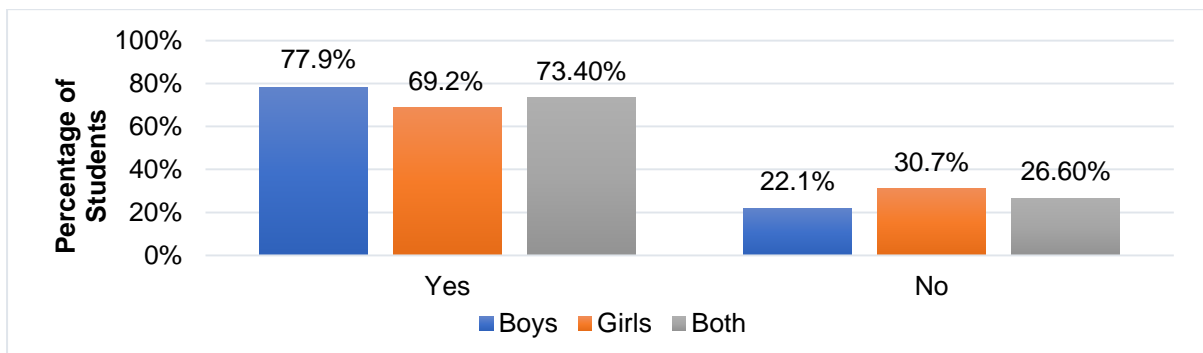
As part of the research, participants were asked to express their opinion on whether the subject is for both genders, or just for male or female (Figure 1). Results show that the majority believe the subject is for both genders. Gender association was further examined separately by female and male students of the sample. The majority of female students tend to believe that the subject is for both genders (81.4%), whereas 17.8% tend to believe that the subject is for boys and only 0.7% for girls. Similarly, the majority of male students believe that the subject is relevant for both genders (65.7%), though 34.3% believe that the subject is for boys rather than girls. None of the male students believe that the subject is for girls.

Figure 26: Is D&T for boys, for girls or both? Participants' response by gender.



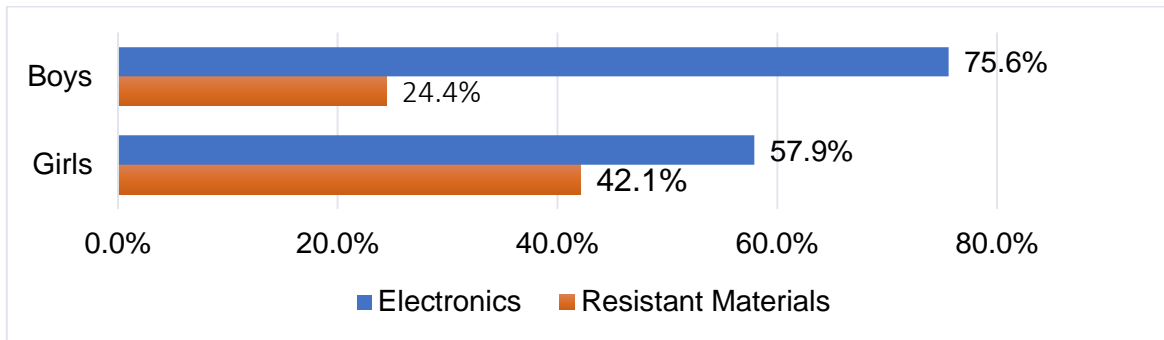
It is clear that both genders enjoy the subject. Figure 2 shows the positive feedback with relevance to how far students enjoy different areas of the subject. When asked if they enjoyed studying D&T 73.4% chose 'Yes' and 26.6% chose 'No'. Analyses by gender is also presented. One can observe that the majority of students who chose 'No' are mostly females (30.7%). It can be concluded that from the students who don't enjoy studying D&T, females strongly agreed more than boys by a bare difference of 8.6%.

Figure 27: Do students enjoy studying D&T? Participants' response by gender.



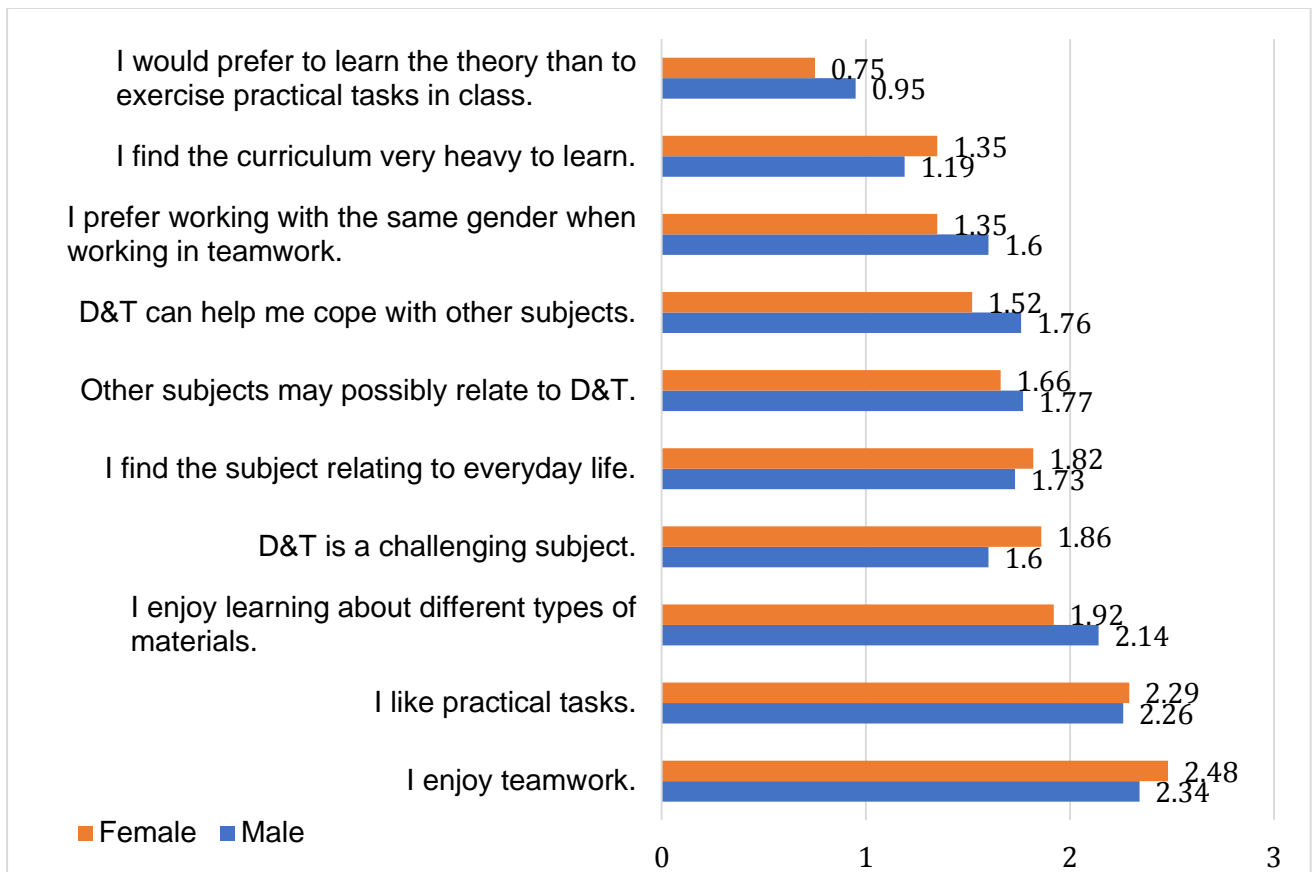
To differentiate between the domains of Electronics and Resistant Materials, all students were asked about those aspects of the D&T curriculum they find most interesting out of these two. As shown in Figure 3, the majority of the students (66.4%) like Electronics, while others enjoy Resistant Materials (33.6%). Figure 3 shows that the majority of female students, (57.9%) engage more into Electronics while (42.1%) prefer Resistant Materials. This is consonant with the literature that indicates that girls do not really like using tools or machinery. Electronics is more abstract and design oriented than resistant materials in the school curriculum. Boys strongly choose Electronics (75.6%) over Resistant Materials.

Figure 28: Area of Interest within D&T by Gender



Students were asked to rate their references in response to given statements as shown in Figure 4. The Mann Whitney U non-parametric test was used to compare the mean rating scores for statements between two independent groups, males and females. Scoring shows males scored significantly higher than females in these statements: a) 'I enjoy learning about different types of materials,' b) 'D&T can help me cope with other subjects' and c) 'I prefer working with the same gender when working in teamwork'. In contrast, females score significantly higher than males in: a) 'I find the curriculum very heavy to learn' and b) 'D&T is a challenging subject'. Meanwhile, for the remaining statements there were no significant gender discrepancies (Figure 4).

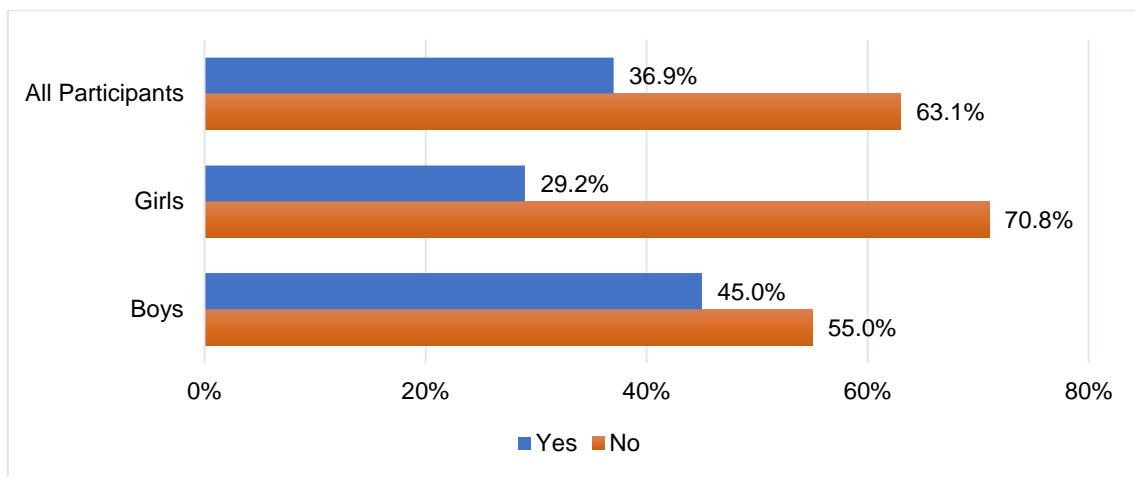
Figure 29: Mean Rating Score by Gender



Interest in opting subject and Influential Systems

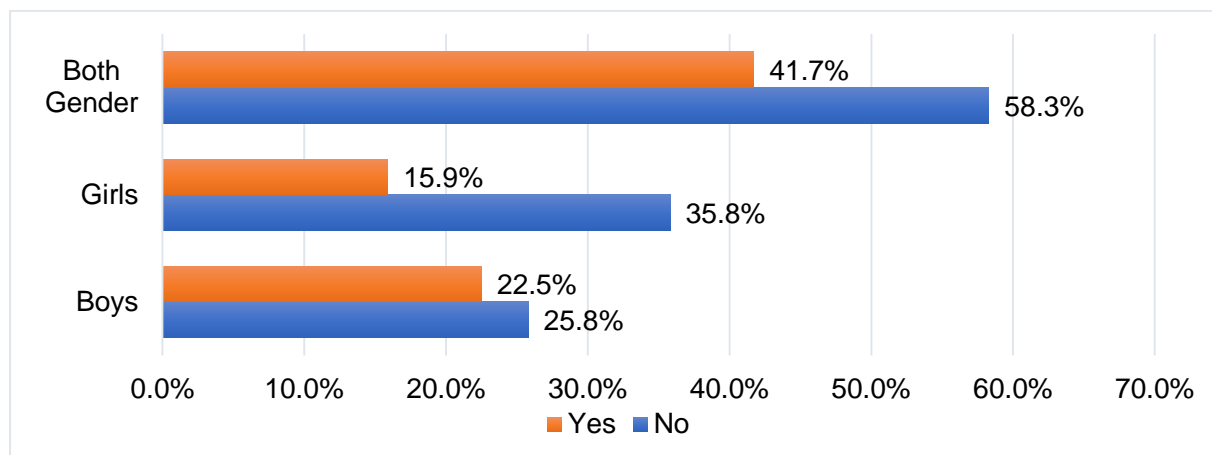
When participants were asked if they would consider choosing the subject as an optional subject, most of the participants (63%) stated that they would NOT choose it, as shown in Figure 5. More than half of the female students (70.8%) stated they would not choose the subject. For males the percentage for not choosing the subject was at 55%. This shows that both gender score considerably high for NOT opting for the subject. This result urged further investigation as to what could be the influential factors involved in such a decision.

Figure 30: Students' Consideration in opting for D&T or not opting for D&T



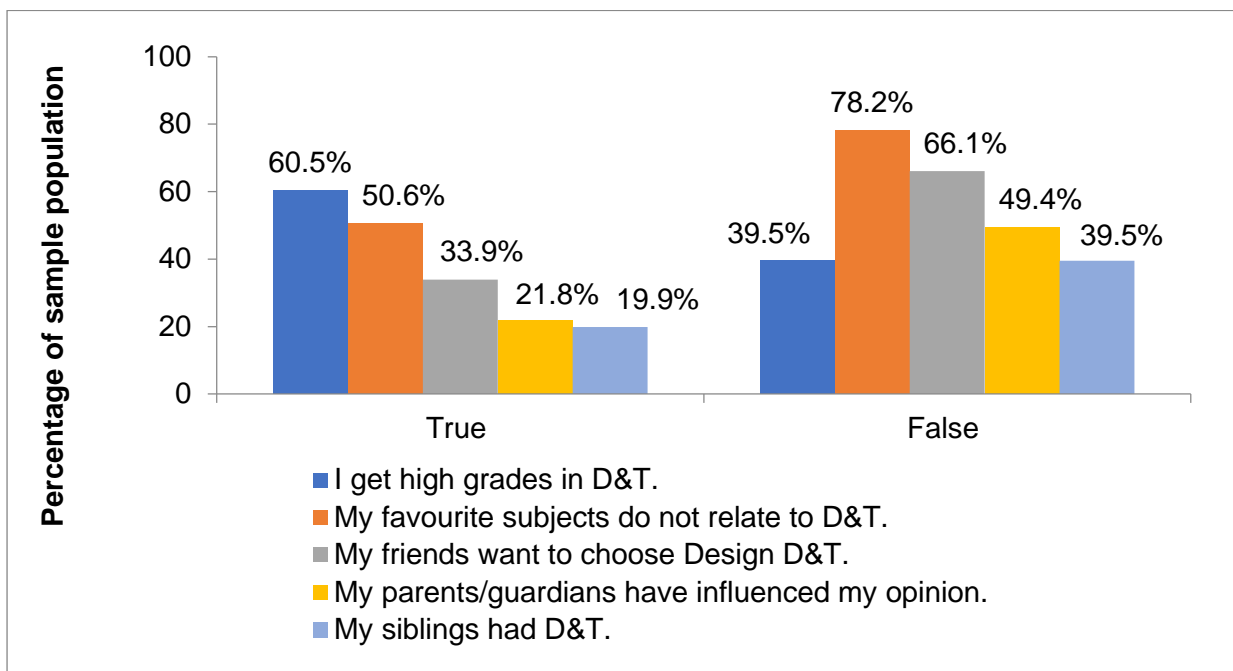
Participants were asked if exposure of the subject makes them more interested in choosing the subject. Figure 6 shows that the majority of females (35.8%) chose 'No'. Similarly, the majority of the male students stated 'No' (25.8%). Over-all results show that the majority of the students (58.3%) chose 'No'. It can be concluded that exposure to the subject is not influencing students' interest in choosing it for further study.

Figure 31: Participants' Response if Exposure is Influencing interest in choosing D&T



The characteristics which could influence participants' choice in opting for the subject were presented in statements with respective 'True' or 'False' options. Figure 7 shows what influential factors could be at play and impacting on the students' decisions. The majority agreed with 'I get high grades' (60.5%), followed by 'My favourite subjects do not relate to D&T' (50.6%) and 'My friends want to choose D&T' (33.6%). Here it can be concluded that students do get high grades in D&T, their favourite subjects do not relate to D&T and their friends do not want to choose D&T. All these could be influential factors which determine if students opt to continue studying D&T.

Figure 32: Influential Factors (True or False)



The types of occupation the students were aspiring to were collected in Table 1. Occupations such as industrial and manufacturing are likely to be chosen by male students is seen in Table 1. On the other hand, female students are more likely to choose hair and beauty, health work and welfare and teaching and training as presented in Table 1.

Students' career aspiration was tested against Gender using the chi-square test for association (Table 1). The null and alternative hypotheses are as follows:

H_0 : There is no association between students' career aspiration and gender

H_1 : There is an association between students' career aspiration and gender

The resulting p-value=0.001 is less than 0.05 level of significance, therefore the alternative hypothesis was accepted. This implies that there exists a significant association between students' career aspiration and gender. The strength of association between the two variables indicates that there is a moderate strength of relationship.

Table 1: Students' Career Aspiration by Gender

		What is your gender?		Total	
		Male	Female		
What profession would you like to pursue when you grow up?	Professional	Count	14	22	36
		%	38.9%	61.1%	100.0%
	Clerical/ Office Work/ Manager	Count	8	20	28
		%	28.6%	71.4%	100.0%
	Health Work and Welfare	Count	3	11	14
		%	21.4%	78.6%	100.0%
	Industrial and Manufacturing	Count	53	14	67
		%	79.1%	20.9%	100.0%
	Teaching and Training	Count	8	23	31
		%	25.8%	74.2%	100.0%
	Humanities and Arts	Count	3	3	6
		%	50.0%	50.0%	100.0%
	Agriculture and Veterinary	Count	0	8	8
		%	0.0%	100.0%	100.0%
	Civil Work	Count	8	2	10
		%	80.0%	20.0%	100.0%
Hair and Beauty	Count	0	18	18	
	%	0.0%	100.0%	100.0%	
Catering	Count	4	2	6	
	%	66.7%	33.3%	100.0%	
Do not Know	Count	30	17	47	
	%	63.8%	36.2%	100.0%	
Total	Count	131	140	271	
	%	48.3%	51.7%	100.0%	

DISCUSSION & CONCLUSION

This study challenges stereotypical assumptions where females do not opt for D&T due to practical tasks and using tools. Issues relating to favourite subjects and career aspiration have been found. The focus of gender research appertaining to the research questions was engaged. Due to circumstances being unaware of key issues within the context of this paper, for future reference it can be recommended to explore the impact of external socio-economic factors or gender-neutral projects.

Student's perception segregated by gender

Findings regarding perceptions were analysed according to gender making use of different statements. Statements such as: a) 'enjoy learning about different materials' and b) 'D&T can help to cope in other subjects' were predominantly marked by males. Suggestions such as: c) 'finding the curriculum very heavy to learn' and d) 'considering it as a challenging subject' were pointed out mostly by females. Weber and Custer's (2005) assumption that curriculum content might lean more towards males' interest can be true. Ashworth and Evans (2001) state that teacher's gender affects female students too. In fact, Thomas S. Dee (2006) found that teacher's gender has impact over student test performance, teacher's perception of students and student's engagement towards academic material.

Perceptions generated through gender could be a result of students' level of confidence and interest (Dee, 2006). Analysing whether there is a relationship between gender and area of interest in D&T, both gender marked 'electronics' as their favourite area, boys ranking higher by 17.7% than girls. Goodness of fit through SPSS suggests there is evidence of a relationship between gender and area of interest, although the strength is weak. Gender ideology shapes girls' beliefs on their competence. Teachers' own mindset and goals about learning can be a powerful tool to influence and change students' mindset (Van der Vleuten, Jaspers, Maas, & Van der Lippe, 2016; Wang & Degol, 2017). To appeal to females and minorities, teachers should have opportunities to design the curriculum to address the needs of such groups in a systematic way (Childress, 2006).

Gender and Career Aspiration

The findings of this study showed that students perceive D&T as a subject for both genders and eliminated the perception of gender association towards the subject (Figure 1). When students were asked if they consider opting for further study of D&T, 63.1% stated No. This is marginally equal in both genders (Figure 5). The study showed that for 58% from the sample population, exposure of the subject did not influence them in choosing D&T later on in their school years. The number of female participants who claimed having been influenced in their choice of the subject because of the compulsory exposure is relatively low (15.9%). Male results show there is minimal difference between those stating that exposure influenced them and those that were not. (Figure 6). Discussion delves in connection to what Wang and Degol (2017) tackle with regards to the ideology that as children grow up, they start to create realistic connections between their interest and future career choices which hence influence subject choice. Considering the sample population of this study, 50.6% state that their favourite

subject does not relate to D&T, whereas 63% of the population does not consider choosing D&T. A significance between the two variables shows that the majority of the sample population does not consider opting for the subject because it does not fit within their preferred subjects. This implies how gender ideology has consequences on educational choices which effects how students evaluate their preferred subject and what is perceived important for future career (Van der Vleuten, Jaspers, Maas, & Van der Lippe, 2016).

Results showed that career aspirations by the students was a detrimental factor in their choice of D&T. Data showed that there is a significant relationship between career aspiration and gender, having a moderate strength of contingency coefficient (0.466). Occupations which are perceived to be related to physical strength such as industrial and manufacturing, civil work and catering are highly represented by males. Meanwhile, teaching and training, professional occupations, clerical/office work and hair and beauty are female dominated. Information by the European Commission (2012) also lists teaching and training as jobs most sought after by females. This situation can be associated to women codes that are generated by the dominant group who establish their needs (Buckley, 1989). Characteristics such as gentle, beautiful, emotionally expressive and sensitive also fit to the occupations highly scored by females (Galdas, 2010). Thus, females being under-represented in STEM subjects, is probably more a result of sociocultural factors and not innate talent as restrictions are created over gender differences (Booy, Jansen, Joukes, & Van Schaik, 2012). Females do not constrain themselves from opting for D&T due to innate talents, but more due to career aspirations. Wang and Degol (2017) argue how women refrain from aspiring STEM related career choices due to lifestyle priorities which can shift to a family-centred goal. Females believe that once they build a family, they would find it difficult to allocate time necessary to keep efficient with current innovations and compete within STEM fields.

Dasgupta and Stout (2014) clearly discuss how stereotypes related to STEM are inaccurate. The ideology regards to such related stereotypes and feminine gender role expectations creates constraints for girls and women to engage in STEM areas. Females are self-guided towards communal concerns while men pursue self-focused goals (Putrevu, Gentry, & Fischer, 2001). Technology education involves real life problems that help both people and society, thus females are probably unaware of the communal values inherent in STEM occupations (Dasgupta & Stout, 2014).

In Malta, a dire need for the dissemination of information about a coherent philosophy of D&T and the potential impact which such study may have on society is being felt at all levels. It would be especially important in the employability sector to invest in the creation of gender-neutral jobs related to D&T so that young students can form their career aspirations towards such jobs. Within the academic sector, it would be important to ensure that appropriate research is conducted relating gender to the uptake and content of technology courses and eventual employment opportunities for both genders.

REFERENCES

- European Commission. (2012). *The current situation of gender equality in Malta- Country Profile 2012*. Retrieved 1 30, 2017, from European Commission: http://ec.europa.eu/justice/gender-equality/files/epo_campaign/130911_epo_country_profile_malta.pdf
- Ashworth, J., & Evans, J. L. (2001). Modeling student subject choice at secondary and tertiary level: A cross-section study. *Journal of Economic Education*, 311- 320.
- Ball , D. L., & McDiarmid, G. W. (1990). The Subject Matter Preparation of Teachers. *W. R. Houston (Ed.), Handbook for Research on Teacher Education*, 437-449.
- Bell, D., Hughes, C., & Owen-Jackson, G. (2013). The (continuing) Gender Debate. In G. Owen-Jackson, *Debates in Design and Technology Education* (pp. 153-165). Oxon: Routledge.
- Booy, C., Jansen, N., Joukes, G., & Van Schaik, E. (2012). *Trend analysis gender in higher STEM education*. Amsterdam, Netherlands: VHTO, National Expert Organisation Girls/Women and Science/Technology.
- Bryman, A. (2008). *Social Research Methods*. Oxford: Oxford University Press.
- Buckley, C. (1989). Made in patriarchy: Toward a Feminist analysis of women and design. *Design Issues*, 3-14.
- Childress, V. (2006). The Diversity Imperative: Insights from Colleagues. *The Technology Teacher*, 6-8.
- Darmanin, M. (1992). The Labour Market of Schooling: Maltese girls in education and economic planning. *Gender & Education Vol.4*, 105- 126.
- Dasgupta, N., & Stout, J. G. (2014). Girls and Women in Science, Technology, Engineering, and Mathematics: STEMing the Tide and Broadening Participation in STEM Careers. *Policy insights from thee Behavioural and Brain Sciences* , 21- 29.
- Dee, T. S. (2006, Fall). The Why Chromosome. *Education Next*, pp. 69-75.
- Department for Education and Skills. (2007). *STEM Learning*. Retrieved 02 11, 2019, from Gender and education: the evidence on pupils in England: <https://webarchive.nationalarchives.gov.uk/20090108131527/http://www.dcsf.gov.uk/research/data/uploadfiles/RTP01-07.pdf>
- Diekman, A., Weisgram, E. S., & Belanger, A. L. (2015). New routes to recruiting and retaining women in STEM: Policy implications of a communal goal congruity perspective. *Social Issues and Policy Review*, 52- 88.
- Directorate for Quality and Standards in Education. (2015). *Design and Technology Curriculum Form 1 & 2*. Retrieved 11 1, 2016, from http://curriculum.gov.mt/en/Curriculum/Year-7/Documents/curric_f1/curric_f1_f2_design_and_tech_2015.pdf
- Education, D. f. (2015). *Design and Technology Curriculum Form 1 & 2*. Retrieved 02 11, 2019, from https://curriculum.gov.mt/en/Curriculum/Year-7/Documents/curric_f1_OLD/curric_f1_f2_design_and_tech_2015.pdf
- European Commission. (2013). *Gendered Innovations. How gender analysis contributes to research. Research and Innovation*. Luxemburg: Office of the European Union.

- Faitar, G. M., & Faitar, S. L. (2013). Teachers' Influence on Students' Science Career Choices. *American International Journal of Social Science*, 10-16.
- Galdas, P. M. (2010). Help seeking for cardiac symptoms: Beyond the masculine- feminine binary. *Social Science & Medicine Vol. 71.1*, pp. 18-24.
- Gjersoe, N. (2018, 3 8). *Bridging the gender gap: why do so few girls study stem subjects?* Retrieved 02 11, 2019, from The guardian: <https://www.theguardian.com/science/head-quarters/2018/mar/08/bridging-the-gender-gap-why-do-so-few-girls-study-stem-subjects>
- Gurría, A. (2018). *Pisa 2015, Pisa Results in Focus*. Retrieved 02 11, 2019, from OECD Better policies for better lives: <https://www.oecd.org/pisa/pisa-2015-results-in-focus.pdf>
- Harding, J. (1997). Gender and Design and Technology Education. *The Journal of Design and Technology Education Volume 2*, 20- 26.
- Harding, J. (2002). Gender and Design and Technology education. In G. Owen-Jackson, *Teaching Design and Technology in Secondary Schools: A Reader* (pp. 237-248). London: Routledge.
- Holth, L., & Mellström, U. (2019). Revisiting Engineering, Masculinity and Technology Studies: Old Structures with New Openings. *International Journal of Gender, Science and Technology, Vol.3, No.2*, 314- 329.
- Kimbell, R. A. (1991). Tackling technological tasks. In B. Woolnough, *Practical Science* . Buckingham: Open University Press.
- Kimbell, R., Stables, K., & Green, R. (1996). *Understanding Practice in Design and Technology*. Great Britain: Open University Press.
- Kimbell, R., Stables, K., Wheeler, T., Wosniak, A., & Kelly, V. (1991). *The assessment of performance in design and technology*. London: Schools Examinations and Assessment Council.
- Murphy, P. (2006). Gender and Technology: Gender mediation in school knowledge construction. In J. Dakers, *Defining technological literacy*. New York: Palgrave Macmillan.
- Navarro, C., & Pulé, S. (2015). Visions for technology education in Malta, Brief history and current issues. In M. Chatoney, *Plurality and Complementarity of approaches in Design and Technology Education* (pp. 302- 312). Marseilles, France: Presses Universitaires De Provence.
- Niiranen, S. (2018). Gender and Technology Education. *M. De Vries, Handbook of Technology Education*, 875- 887.
- Purchase, D. (2005). The last ten years: Change in Malta. *Paper presented at the PATT-15. Technology Education and Research: Twenty years in Retrospect*.
- Putrevu, S., Gentry, J. W., & Fischer, E. (2001). Exploring the Origins and Information Processing Differences Between Men and Women: Implications for Advertisers. *Academy of Marketing Sciences Review*, 1- 16.
- Salminen-Karlsson, M. (2007). Girls' Groups and Boys' Groups at a Municipal Technology Centre. *International Journal of Science Education*, 1019–1033.

- Schutt, R. K. (2012). *Investigating the Social World. The Process and Practice of Research*. USA: SAGE Publications.
- Spendlove, D. (2002). Boys' performance in design and technology: The context and the issues. In S. Sayers, J. Morley, & B. Barnes, *Issues in design and technology teaching* (pp. 153- 168). Oxon: Routledge.
- Stets, J. E., & Burke, P. (2000). Femininity/ Masculinity. In E. F. Borgatta, & R. J. Montgomery, *Encyclopedia of Sociology, Revised Edition* (pp. 997- 1005). New York: Macmillan.
- Sultana, R. G. (1995). Vocational Secondary Schools in Malta: quality of education and the reproduction of inequality. *The Vocational Aspect of Education*, 51- 67.
- Tyler, T., & Osborne, J. (2012). Assessment and Evaluation. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie, *Second International Handbook of Science Education* (pp. 597- 626). New York: Springer.
- Van der Vleuten, M., Jaspers, E., Maas, I., & Van der Lippe, T. (2016). Boys' and girls' educational choices in secondary education. The role of gender ideology. *Educational Studies*, 181-200.
- Wang, M.-T., & Degol, J. L. (2017). Gender Gap in Science, Technology, Engineering, and Mathematics (STEM): Current Knowledge, Implications for Practice, Policy and Future Directions. *Educational Psychological Review*, Vol. 29, 119- 140.
- Weber, K., & Custer, R. (2005). Gender-based Preferences toward Technology Education Content, Activities, and Instructional Methods. *Journal of Technology Education* Vol. 16 No. 2,, 55- 71.

Existential risk in technology education.

Markus Stoor



Markus Stoor
Umeå University
Sweden
markus.stoor@umu.se

ABSTRACT

Recent advances in machine learning and biotechnology inspires a longer time perspective on possible technological change. One such perspective is provided by the study of existential risk, namely risks that endanger the survival of the whole of humanity. Central takes from existential risk studies are of relevance for discussion in technology education since they include a clear indication of nuclear weapons and emerging technologies as the main short term source of existential risk and emphasizes the huge ethical importance of continued human survival into the long future. This is clearly of interest for a Technology subject like the Swedish where the societal dimension of technology is mandated content. Due to the large uncertainties surrounding existential risk the educational implications are unclear. To begin to make sense of these implications a small study of ethical beliefs about existential risk among 14-15 year old lower secondary students were undertaken. A vignette question building on one of Parfitt's thought experiments was administered to a convenience sample of around 100 students. Half of them answered that the death of the last percent of humans when 99% already have died would be a much worse thing than the nuclear war that killed the 99%. This result is argued to be an indication of that the unique badness of human extinction is within common ethical consideration of lower secondary students. The main conclusion is that technologically driven existential risk is a phenomenon worthy of further discussion in technological education due to the potentially high ethical importance but that no clear implications other than that can be made at this stage.

Key words: Existential risk, Technology education, Swedish compulsory school

Existential risk

The last years have seen much writing about coming technological change bearing profound societal impact. Especially advances in machine learning have inspired visions of a society transformed by coming AI and automation technology (Brynjolfsson & McAfee, 2014) (Schwab, 2017). Others have also pointed at the huge potential for good and bad of human biotechnology (Harari, 2017). But this intellectual environment have also been kind to a much darker vision of future - existential risk - or future negated. Existential risk is the term for risks that endanger the whole of humanity.

Human extinction was discussed during the height of the cold war as a consequence of the possibility of global nuclear war raised by the massive stockpiles of nuclear weapons. While the foundation of the existential risk discipline stems from that age, for instance from Parfit (1984), the term existential risk and the research paradigm can be traced to an influential paper of Bostrom (2002). Since then a field of existential risk studies have coalesced around Bostrom and a few other central scholars, today mainly based in Oxford, Cambridge, Berkeley and Boston. *Here be dragons* by Häggström (2016) is a contemporary introduction to the field. Central takes include the role of emerging technology, the large uncertainties and the potential huge ethical importance.

Existential risks are often (Bostrom & Cirkovic, 2011; Häggström, 2016) categorized based on whether they emanate from nature or from us humans ourselves. Risks emanating from nature include things like a large asteroid hitting earth, a gamma burst from a nearby supernova and volcanic activity on a scale like that which produced the Deccan traps geological formation by covering up to half of India with 2000 m of basalt. The original case for possible existential risk from human activity is a global nuclear war. Other candidates that have been proposed is uncontrolled geoengineering (S. D. Baum, Maher, & Haqq-Misra, 2013), bioengineered pandemics (Millett & Snyder-Beattie, 2017) and artificial superintelligence misaligned with human values (Bostrom, 2014).

To divide existential risk between naturally occurring and human driven is useful when trying to assess the probabilities involved. While the whole field is characterized by large uncertainties the situation regarding the known possible naturally occurring risks is much better than in those linked to human activity. Geological records provide data on the earlier super volcanic activity as well as on large asteroid impacts. We know that we have had nuclear weapon stockpiles large enough for a global war for 50-60 years and we and our civilization still is here this far. That is however compatible with very different yearly probabilities. The situation with estimating probabilities for emerging technological possibilities of human extinction is still more difficult. A common view in the field articulated for instance by Häggström (2016) is however that in the shorter term (the coming centuries) the probability of the natural risks is dwarfed by the technological ones.

That human extinction would be really bad is a widely shared notion both in the general population and among those specializing in principled ethical reasoning. But badness comes on longer scale than commonly imagined according to existential risk ethicists. That human extinction would be extremely and uniquely bad is a central tenet in their reasoning. This comes down to the vast possible value that could be realized over a very long time of human existence and that would be lost in the case of extinction. Even if humanity in the long run remained bound to the planet Earth it might still flourish for a billion years (Bostrom, 2013).

My view is that existential risk is of possible interest for technology education due to the combination of the technological sources and the huge ethical importance.

Technology education and existential risk

Technology as a school subject is construed in different ways in different school systems. In this article arguments about existential risk in technology education builds upon a version of the technology subject as a school subject devoting substantial curricular priority to the societal dimensions of technology development and use. The standpoint is made from a Swedish technology subject perspective (Skolverket, 2011) but should transfer to other subject conceptions, for instance the one outlined in the ITEA standards for technological literacy (ITEA., 2007). It is a standpoint about a technology education mindful of phenomena like those listed by Olson (2013) and leaving ample room for the curriculum emphasis described by Klasander (2010) as the democratic citizen emphasis. Some of the reasons for the societal aspects of the Swedish technology subject is summarized as "*Teaching in*

technology should essentially give pupils the opportunities to develop their ability to” ... “assess the consequences of different technological choices for the individual, society and the environment” in the national curriculum (Skolverket, 2011). In that context existential risk represents one endpoint of the scale of potential impact of technology.

If one is to accept the scholarly view about the large ethical importance and a non-negligible likelihood the large uncertainty makes it hard to put an upper bound on the importance. This matters since our normal duties as education researchers and teachers with respect to our pupils and the surrounding society assumes normal bounds. For instance can we normally teach about all things deemed sufficiently important. That intuition might not hold in extreme situations. The lack of an upper bound of the importance of existential risk implies that we don't know if it could be treated as an interesting and possibly important phenomena maybe or maybe not worthy of curricular inclusion or if our seemingly normal situation actually is extreme and how we approach existential risk is close to the only thing that matters from an ethical birds' eye view of the whole humanity, past, present and future. To me this suggests that we should try to be unusually careful and reason through how to think about existential risk and technology education before committing to a view or larger scale action.

This goes double so because of the potential blowback. In the case of eventual superintelligence and potentially associated risk there is a sometimes heated debate where some positions seem to be held with much more certainty than warranted due to the lack of evidence and expert disagreement. A survey of experts in machine learning gave wide ranging estimates for when machines will outperform humans in certain complex domains (Grace, Salvatier, Dafoe, Zhang, & Evans, 2018). Still some experts hold a strong and certain view about how it is impossible at the same time as other experts mirror them in certainty but reverses direction and view it as inevitable and arriving shortly. Baum (2018b) describes this debate as mostly intellectually honest but with a big potential for oncoming politicization due to the uncertainty and big vested interests. As it also can be argued that the general public isn't the most important group to inform (Seth D. Baum, 2018a) and premature curricular decisions could easily end up doing more harm than good even if existential risk worries turn out to be well founded.

So while there clearly are things that could be better understood both in the study of existential risk and in the technological fields of interest in order for us technology educators to better grapple with curricular recommendations significant uncertainty will remain. Beside those external inputs there is also the knowledge of our own field. We can both investigate phenomenon that might be of importance and use related examples from the educational field such as teaching about climate change. I propose that one thing that might be of importance is if the central ethical tenet of existential risk - that human extinction is much worse than other bad things - is within the range of ethical consideration of students in the age whose curriculum is under debate.

Ethical beliefs about existential risk among lower secondary students

Since existential risk might be an important phenomena in the area of the societal aspects of technology and the importance stems from the ethical valuation of a long future for humanity it would be good to get an indication of whether this ethical standpoint is considered reasonable in the age group receiving technology education. The last stage of obligatory technology education in Sweden takes place in lower secondary (three school years roughly between 13-15 years old). Therefore I want to know how such students consider human extinction in relation to other really bad things. To get an indication of that I constructed a vignette question out of an elegant thought experiment made by Parfit (1984). He compared the ethical loss of value going from peace to a nuclear war killing 99% of humanity to the loss going from that situation with 99% already dead to total extinction and argued that the latter

loss was far bigger than the former. The vignette question was then answered by students in the later part of the lower secondary.

The study was carried out in the setting of a Swedish international lower secondary school inviting an existential risk scholar to hold a lecture for multiple classes in grades 8 and 9 (14 and 15 year old pupils). The general education of the parents to the students attending the school is high and the academic results are good. The lecture was attended by around 200 pupils. The original plan was to administer a very short two section questionnaire before and after the lecture where half of the pupils would answer the main question before the lecture while the other half would answer it afterwards. Due to my poor handling one part of the planned study was compromised and only the surviving part is reported here.

Method

198 unmarked and randomized envelopes each containing one of two sets of white (before) and blue (after) questionnaires were handed out to pupils immediately before the lecture. The pupils were then informed of the voluntary nature of participation, the anonymity guaranteed by randomization and of my strong desire for them not to answer unless they understood and related to the question. Five minutes were given to complete the first part of the questionnaire and then the lecture commenced. After the lecture another five minutes were given to complete the second part. Due to insufficiently clear communication many pupils filled out the blue (after) part before the lecture had ended, either before or in some cases during the lecture. This compromised the possibility of comparing the before and after answers of the main question and consequently the compromised results were dropped from the study. The nature of some of the questions on the blue (after) questionnaire belonging to the white (before) main question seem to have little sensitivity to when they were answered. Therefore the answers to the questions about whether the main question was easy to understand and how sure they are about their main question answer is reported even though they might have been answered at the wrong time.

The main question was a vignette question illustrated by a diagram. It is shown in its entirety as figure 1. The options are construed so that option 1 (a war killing almost everyone is much worse than the subsequent death of the last remaining humans) and option 2 (the war and the subsequent extinction is of comparable badness) are evidence against that the pupil share the ethical standpoint of existential risk as uniquely important. Option 3 (the subsequent extinction is much worse than the initial war) indicates the opposite.

Result and discussion

93 envelopes containing the main question as the first part were collected. Of those, 6 were unanswered and 2 had ambiguous answers. These are reported together. Of the remaining 85 answered questionnaires 38 were answered with either option 1 or option 2. 47 were answered with option 3. These results are shown in table 1.

Table 1. Main results.

Option 1	Option 2	Option 3	No answer	Total
15	23	47	8	93

Around half of the asked students indicated that they concur with Parfit in viewing the death of the last percent and thereby the extinction of humanity as much worse than the death of 99% of all humans. The other half does not.

What I am interested in is whether the broad notion of human extinction a something almost uniquely bad is within the range of common consideration in the age group or not. I think that question can be answered positively even with much lower option 3 percentages if we can be sure that those percentages actually means that the pupil in question concur with the notion of human extinction as almost uniquely bad. With such assurance I would argue that it would within common consideration if one out of four answered option 3. Less than one out of eight concurring would however be a problematic number to reconcile with regarding human extinctions as almost uniquely bad as within common consideration. Since there are only three options a significant number of students just ticking a box at random or misunderstanding the rather abstract and complicated question would be very worrisome for the interpretation of the results. This is somewhat mitigated by the results from the question about whether the vignette question was understandable. The results are found in table 2.

Table 2. Answers to: “How difficult was it to understand the question on the white paper?”

Easy	Neither easy nor difficult	Difficult	No answer	Total
36	35	9	13	93

Most of the pupils found the main vignette question to be understandable. I find this to be a reason to accept the answers to the vignette question as mainly meaningful. Together with the high proportion answering option 3 (around half of all questionnaires, answered as unanswered) I interpret this as a strong indication of that human extinction is something almost uniquely bad is well within common consideration in this group.

Since this result is based on a convenience sample of students who can't be said to be representable for the broader Swedish population of lower secondary students there is good reason to be very careful in extending interpretation to that population. But since the proportion answering option 3 would be needed to be more than halved in the broader population in order to change the interpretation I would still say that this result is weakly indicative even for that population.

Existential risk in the Technology curriculum?

Considering the earlier argumentation and the small study of ethical beliefs I think that the main thing that can be said about existential risk and technology education at this stage is twofold. It might be important to do the right thing and we don't know what the right thing is.

In search for the right thing I think it would be good to don't get too bogged down in the details of likelihood assessment and existential risk scenarios. While these definitely is of importance there might be implications of the broader technologically driven existential risk scenarios for a partly civic minded technology subject that doesn't include direct education about existential risk. Such examples worthy of further consideration might be an increased focus on how consequential technological decisions are made at a societal scale or a larger presence of the longer timescales of technological change. Maybe what the uncertain possibility of technological existential risk calls for is a greater awareness of how transformatory the technologies of the Neolithic revolution were for human existence?

Read the three scenarios and answer the question.

Scenario A Peace

After 20 years of tension and a fast nuclear arms race a crisis occurs. The crisis subsides and the tension between the countries of the world slowly dissolves. 1000 years later **peace** reigns and humanity flourishes like never before.

Scenario B War – almost everyone is killed but humanity recovers

After 20 years of tension and a fast nuclear arms race a crisis occurs. A global nuclear **war breaks out and almost everyone is killed** in the war or in the coming few years. But 1000 years later there still is humans alive and **humanity has recovered**.

Scenario C Humanity goes extinct

After 20 years of tension and a fast nuclear arms race a crisis occurs. A global nuclear war breaks out and almost everyone is killed in the war or in the coming few years. 1000 years later the last humans have died and **humanity goes extinct**.

Question.

Is it worse to go from **peace [A]** to a **war where almost everyone is killed [B]** or is it worse to go from a **war where almost everyone is killed [B]** to the **extinction of humanity [C]**?

Tick the option that best describes what you think.

- 1. It is much worse to go from **peace [A]** to a **war where almost everyone is killed [B]**.
- 2. Neither of the both steps is much worse than the other.
- 3. It is much worse to go from a **war where almost everyone is killed [B]** to the **extinction of humanity [C]**.

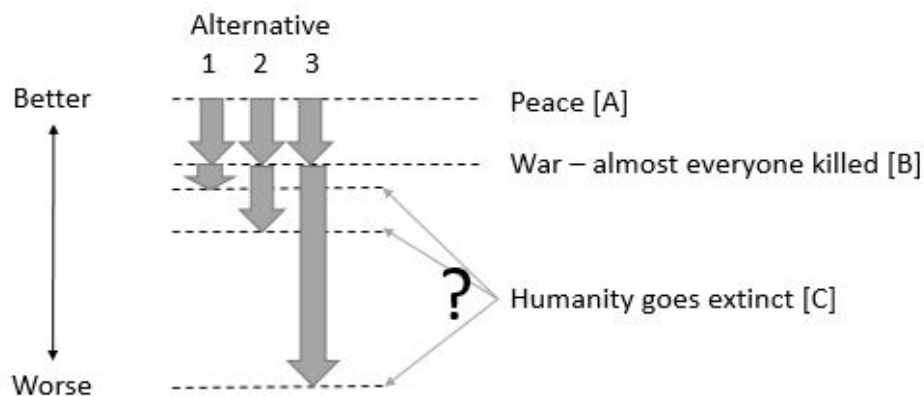


Figure 1. The vignette question.

References

- Baum, S. D. (2018a). Countering Superintelligence Misinformation. *Information. An International Interdisciplinary Journal*, 9(10), 244.
- Baum, S. D. (2018b). Superintelligence Skepticism as a Political Tool. *Information. An International Interdisciplinary Journal*, 9(9), 209.
- Baum, S. D., Maher, T. M., & Haqq-Misra, J. (2013). Double catastrophe: intermittent stratospheric geoengineering induced by societal collapse. *Environment Systems & Decisions*. Retrieved from <https://link.springer.com/article/10.1007/s10669-012-9429-y>
- Bostrom, N. (2002). Existential risks: analyzing human extinction scenarios and related hazards. *Journal of Evolution and Technology / WTA*, 9.
- Bostrom, N. (2013). Existential Risk Prevention as Global Priority. *Global Policy*, 4(1), 15–31.
- Bostrom, N. (2014). *Superintelligence: paths, dangers, strategies*. Oxford University Press Oxford.
- Bostrom, N., & Cirkovic, M. M. (2011). *Global Catastrophic Risks*. OUP Oxford.
- Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. WW Norton & Company.
- Grace, K., Salvatier, J., Dafoe, A., Zhang, B., & Evans, O. (2018). When will AI exceed human performance? Evidence from AI experts. *The Journal of Artificial Intelligence Research*, 62, 729–754.
- Häggström, O. (2016). *Here Be Dragons: Science, Technology and the Future of Humanity*. Oxford University Press.
- Harari, Y. N. (2017). *Homo deus : a brief history of tomorrow*. New York, NY: Harper, an imprint of HarperCollinsPublishers.
- ITEA. (2007). *Standards for technological literacy – content for the study of technology*. ITEA (The International Technology Education Association). Retrieved from <https://www.iteea.org/67767.aspx>
- Klasander, C. (2010). *Talet om tekniska system: förväntningar, traditioner och skolverkligheter*. Norrköping: Institutionen för samhälls- och välfärdsstudier, Linköpings universitet.

- Millett, P., & Snyder-Beattie, A. (2017). Existential Risk and Cost-Effective Biosecurity. *Health Security, 15*(4), 373–383.
- Olson, J. K. (2013). The Purposes of Schooling and the Nature of Technology. In M. P. Clough, J. K. Olson, & D. S. Niederhauser (Eds.), *The Nature of Technology: Implications for Learning and Teaching* (pp. 217–248). Rotterdam: SensePublishers.
- Parfit, D. (1984). *Reasons and persons*. Oxford: Clarendon Press.
- Schwab, K. (2017). *The fourth industrial revolution*. Penguin UK.
- Skolverket. (2011). Curriculum for the compulsory school, preschool class and the recreation centre, 2011.

What are they doing? Tool use and self-image of girls aged 9 to 12 when engaging in technology education.

Ulrika Sultan, Cecilia Axell, Jonas Hallström



Ulrika Sultan
Linköping University
Sweden
ulrika.sultan@liu.se



Cecilia Axell
Linköping University
Sweden
cecilia.axell@liu.se



Jonas Hallström
Linköping University
Sweden
jonas.hallstrom@liu.se

ABSTRACT

In the field of technology education differences between girls and boys have been researched for some time but there is still a lack of knowledge about what exactly these differences consist of, and why they exist. The aim of this study is to explore tool use and self-image of girls aged 9 to 12 when engaging in technology education. Data was collected over a course of two weeks, involving one Swedish compulsory school and three different classes with pupils aged 9 to 12. The data collection method used for this explorative study was unstructured observations made in-class during fourteen hours of teaching. Social identity theory is used as a theoretical framework to gain knowledge and clues as to why girls lose their interest in technology (education) as they get older. The results of the classroom observations revealed that, although the girls were not aware of it, they still confirmed gender stereotypes about girls and technology by e.g. adopting a social identity as not being technical. This study thus largely confirms the prevailing descriptions in previous research on girls and technology education.

Keywords: girls' engagement, technology education, social identity, stereotyping, prototyping, primary

Introduction

Research about girls' interest and engagement in technology education in secondary education has been explored. However, there is still a lack of research regarding girls and technology education in the early years of school (Kim, Sinatra & Seyranian, 2018). Previous studies, both the few on primary and the bulk on secondary schools, primarily concentrated

on the differences between girls' and boys' engagement in technology education. As Hussénius, Andersson, Gullberg and Scantlebury (2013) argued, too many studies are restricted to comparing female and male students on variables such as students' achievement and attitudes. Previous research (e.g. Kim, Sinatra & Seyranian 2018; Turja, Endepohls-Ulpe, & Chatoney, 2009) suggested that while males are portrayed as more interested in technology than females, societal factors such as upbringing, education and the labour market may discourage girls' interest in and engagement in technology. This begs a new way of studying girls' relationship to technology, particularly in relation to education in which girls' interest and engagement are formed from an early age. Social identity theories point to how the construction of an identity as not being technical can manifest itself in and affect girls. Therefore, in this study we focus on girls only, to gather clues and gain knowledge about their relationship with technology apart from boys, to the extent that this is possible. The aim of this study is thus to explore tool use and self-image of girls aged 9 to 12 when engaging in technology education.

Who engages with technology is often identified with a stereotype, which is the most normative representation of a group in a social context (Hogg, Terry & White, 1995; Turner, 1991) and in technology the stereotype tends to be white and male. The notion of prototype is different from stereotype in the way self-identity is seen as being created. The notion of prototype focuses on a person adapting an identity and is therefore more flexible, whereas stereotype has to do with how others view one's abilities and traits (Fox, 2011). When comparing genders, one gender will often be considered as the normal and the other not (Turja, Endepohls-Ulpe, & Chatoney, 2009). Boys are in this sense both a prototype and stereotype for engagement and interest in technology education and therefore define the norm. In earlier research this stereotype is linked with traits such as being handy, objective, rational, and non-emotional (Brickhouse, 2001). Given that stereotypes in many STEM fields, including technology, tend to be male (Berg & Lie, 1995; Cheryan et al., 2015), female students in these fields are less likely to define themselves as prototypical technologists.

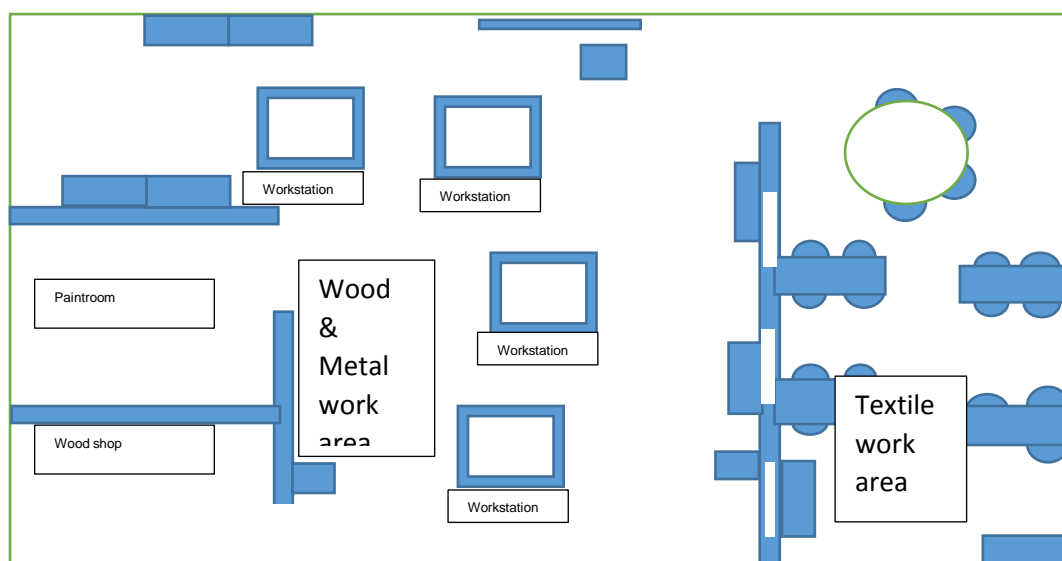
Labelling oneself as technical or untechnical is therefore a type of social identity, or prototype. Developing an identity as being technical has two aspects. One is a psychological sense of belonging. Cheryan, Master, & Meltzoff (2015) suggest that the social environment and feelings of belonging in the field of STEM may play significant roles in nurturing or hampering a STEM identity. The second aspect is social acceptance, or having the community of technology (education) recognise the individual as a group member who fits in. When technology is constructed as a male domain and comprising male attributes, such as logic and technical knowledge, this tends to produce negative stereotyping surrounding girls (Sanders, 2005). Girls are also more likely to be subjected to negative stereotyping in settings where technological ability is seen as a being a natural trait (Emerson & Murphy, 2015). In these settings, girls are more likely to disengage and adapt a social identity as not being technical (Kim, Sinatra & Seyranian, 2018; Knopke, 2015).

Method

The data of this study was obtained from unstructured observations of technology classes. The purpose of the unstructured observation is to develop a narrative (Bryman, 2016) and we used the method as a vehicle to explore tool use and self-image of girls aged 9 to 12 when engaging in technology education. The data collection spanned a technology course of two weeks, involving one Swedish compulsory school and three different classes with pupils aged 9-12 during 6 lessons and a total of 14 hours. To get access to the field, an inquiry was sent out on the social media platform Twitter. One technology education teacher responded and gave us access to the teachers' classroom and pupils. The teacher acted as gatekeeper and helped us determine when was the best opportunity to perform the study, and s/he also established a relaxed environment for the research process. The teacher also became an important discussant when trying to make sense of the collected data. Furthermore, the teacher's knowledge about the classroom setting and how to best obtain consent from the participants' parents proved valuable for the study.

The data collection was carried out during a total of six technology lessons, in a classroom dedicated to educational sloyd. Sloyd (in Swedish, *Slöjd*), is a compulsory, handicraft-based subject in Swedish schools, year 1-9. In Sweden, technology and sloyd often share equipment and classrooms. There were two work spaces in the same classroom, only divided by a wall which mostly consisted of windows; one space intended for wood and metal work, and one for textile work.

Fig 1. Overview of the sloyd classroom where the technology classes of the study took place.



In the unstructured observations, which were carried out by the first author, we as researchers had a general idea of what might be significant (Given, 2008). The starting point for the observations were to document as much as possible about the physical setting, the context, the participants' gender, and their activities. As the first author focused on the girls, their interactions with each other were considered of importance, as they could be of interest regarding the aim of the study. Data from the observations was collected by using field notes. There were no checklists or coding schemes to follow during the observations. The first author observed and took notes of conversations between the girls, between girls and teacher, and made notes on what tools the girls used during class, and how they portrayed themselves in relation to technology. Thus, the field notes consisted of descriptions of the activities, quotes from conversations and the first author's own reflections during the activities. The observations were documented in a narrative style, and were analysed using qualitative content analysis (e.g. Elo & Kyngäs, 2008) in which the data is organised and categorised after repeated reading and analysis in a hermeneutic tradition.

The analysis was performed in several steps. The first step was an "open" reading of the field notes to obtain an overall idea of their content. In the second step, meaning units with reference to what was observed in relation to girls' tool use and how they portrayed themselves in relation to technology, were identified. A meaning unit consisted of one or more sentences or paragraphs of a narrative from the field notes. In the third step, the meaning units were condensed, and in the fourth step, an interpretation of the underlying meaning in relation to social identity theory and previous research, was made.

The ethical principles for research were followed by informing the participants about the purpose of the observations and about their right to consent and to discontinue their participation should they wish to. Consent was also obtained from parents. The participants were also informed about their participation being anonymous, and that the data would not be used for anything else than research purposes (Swedish Research Council, 2002).

Results

During the observations the first author listened to and documented the girls' conversations. The included conversations are highlights taken from the field notes, and should be read as excerpts from classroom conversations that illuminate aspects of tool use and self-image of 9-12-year-old girls in a Swedish technology classroom. **Descriptions of an activity** are marked with **[DESCRIPTION OF ACTIVITY]**. The reflections on the activities are marked with **[REFLECTIONS]**. Actual citations are marked with who is talking.

Girls aged 9 and 10 (year 3-4) (one lesson)

[DESCRIPTION OF ACTIVITY]

The teacher showed the pupils a YouTube video about robots. The pupils were then instructed to work together in groups of 3-4 pupils in every group. The pupils got to choose who they wanted to work with. The eight girls in the class were divided throughout the smaller group constellations except for one group with only girls, four girls. This group would turn out to be the most verbal one in the coming group discussions. When the groups were decided and the pupils had gathered round a workstation, they were instructed to first think alone and later agree on what kind of robot they would like to construct a model of. The pupils were instructed to have an individual thought of what kind of robot they would like to have, and the group must then reach a consensus about what capabilities and functions the groups' robot should have. The pupils should use notebooks and sketch the robot they would like to have, write down what its function is, and finish with giving the robot a name. The teacher then told the pupils to search on Google for drawings of robots. Then they should draw all the ideas that they could come up with. The pupils googled and discussed. The group with only girls got into an intense discussion about what kind of materials they wanted to use in their model and what kind of functions they wanted their robot to have.

[REFLECTIONS]

The girls in the mixed group did not display the same intensity among the participants in the discussions as the girls in the all-girl group; their roles were more confirming and agreeing with the rest of the group. In one group, however, one girl led her group discussions, taking on a leadership role and challenged the groups' ideas. This girl suggested an angry bull with glowing eyes as the group's robot model. Groups with only girls wanted the robot to do household chores, such as making the bed, doing the dishes, etc.

Girls aged 11 (year 5) (two lessons)

[DESCRIPTION OF ACTIVITY]

The assignment that the pupils were supposed to do here was to create a space diorama using one or more simple machines to move the planets, the sun or spaceships. The pupils were divided into mixed-gender groups with 4-5 pupils in every group. In the group located in the paint room the following conversation took place:

Girl 1: I don't like technology **[comment made to nobody special]**

Girls 2 to Girl 3: One will instruct and the other will sketch on what needs to be sawed. Ok?

Girl 3: If we do Saturn we need to do the rings also.

[They made their sketch and walked over to the jig saw, to ask the boys for help with the saw].

[REFLECTIONS]

The girls mostly asked each other for help when they got stuck. Glue guns were the specific tool of choice for the girls. Even when other tools could make the work easier they chose to

use the glue gun. When it came to decorating the dioramas, the girls took the lead and painted what they wanted, even taking a dominating position.

Girls aged 12 (year 6) (three lessons)

[REFLECTIONS]

The lesson assignment was to build models of the different parts of a common playground; a fair, swings and carousels. There was a clear division among the groups. Girls only worked with girls. Girls and boys engaged in small talk from time to time, but they worked separately as regards gender.

[DESCRIPTION OF ACTIVITY]

Here the different groups were the pupils' own choice:

Girl 1: [Walking around the room.] I'm so bad at this.

All girls except for three of them went to the paint room. The teacher went in after them asking what they were then working on. The girls split up and went back into the wood and metal work space in the room. Two of them sat down by the computer. They were creating a chocolate wheel and wanted to make and print a word document of a table consisting of columns and rows with names of colours to put on their chocolate wheel.

Girl 2 to girl 3: I'm no good at this. One must do it another way to be able to paint [it later]. It has to be nice in terms of colours.

[Girl 3 tried to add a line to the document].

Girl 2 to passing boy: Can you help us [with the computer]?

Boy: No, I don't know how it works.

Girl 2: But you are good at computers.

Girl 2 to girl 3: If we insert a table, one here, and add one here then it might work. Yes.

Girl 3: Yes.

Girl 2: Yes.

Teacher: Hey girls. Everything ok? Are you making a table? You can decide how many rows and columns you want straight away. You don't have to make them yourselves.

The teacher left to help their classmates.

[The girls continued working on the computer]

Girl 2: I'm not good at this.

Girl 3: I don't get it.

[The girls turned to the same boy as above]: How do you spell lavender?

Boy: I don't know. I don't even know what that is.

The girls continued working at the computer, choosing the colours they wanted to use in the table imbedded in their word document, making the table look nice. They were meticulous about the spelling of every word. During a period of 20 minutes I counted them saying 11 times that they don't know, don't understand or that they are not able to work with the computer.

Girl 4: [asks teacher] – can girl 5 use this piece of wood and saw it?

Teacher: Yes, no. I'll help her. Be careful [to girl 5].

[Girl 5 used the jig saw by herself, supervised by the teacher].

Girl 5 to teacher: Can I drill a hole?

[REFLECTIONS]

The teacher did not have a chance to answer before girl 5 asked a boy in the class for help with the drill.

[DESCRIPTION OF ACTIVITY]

Three of four girl groups preferred to work in the textile work section of the room instead of in the wood and metal work part. They chose to integrate fabric in their models. Pink, lilac, blue and white coloured fabric. Or “pretty fabric”, as one of the girls explained.

[REFLECTIONS]

Instead of using a variety of tools the girls mainly used glue guns to construct their models. This they chose to do although they also expressed the knowledge that some tasks would be easier solving with other tools.

Discussion

The results of the analysis of the observations do not show the girls as having been subjected to negative stereotyping (cf. Emerson & Murphy, 2015). Aspects identified as necessary for the creation and implementation of successful STEM education projects for girls include the ability of students to form collaborative groups and participate in solving problems that they identify as meaningful, relevant to them and open-ended (Billington et al., 2014; Denner & Werner, 2007), which the teacher in our study provided. However, although the assignments were gender neutral and the teacher supportive, particularly the 11-year-old girls disengaged and adapted a social identity prototype as not being technical, as discussed by Kim, Sinatra & Seyranian (2018). These girls frequently expressed that they do not like technology, or that

they are not good at technology, in contrast to the boys which were seen by the girls as technical – despite one of the boys even protesting to the label on him as being “good at computers” (cf. Virtanen et al., 2015). Our results regarding the 11-year-old girls would thus seem to align with earlier research claiming that girls often lose interest in and confidence regarding technology from this age (e.g. Ardies, De Maeyer & Gijbels, 2015; Swedish Schools Inspectorate, 2014).

The paper thus gives insight into how 9-12 year-old-girls expressed the prototype that they were not technical as well as what kind of tools they chose to use during technology lessons. The results suggest that the girls in this study tended to fulfil a negative technological identity and choose to use female-coded artefacts such as glue guns and fabric, which may be an obstacle to girls’ unbiased engagement in technology education. Therefore, it might be of importance to reinforce the connection between girls and technology from a social identity perspective. This needs further exploration and the next step exploring this issue can be performing focus-group interviews with groups of girls, since there is variety and differences even between girls in relation to technology.

This study should be seen in its own context and no generalisation should be drawn from it. The method of unstructured observations has the advantage of one often being able to observe relatively rare or unusual behavior that might be missed with more deliberate sampling methods (Emerson, Fretz, & Shaw, 2001). It can be a problem when the researcher expects to see events that are not there and unconsciously creates those events. In this study we tried to be as open-minded and explorative as possible, which also goes for the first author when exploring what girls were doing during lessons in technology education. The research aim reflects this openness.

References

Ardies, J., De Maeyer, S., & Gijbels, D. (2015). A longitudinal study on boys’ and girls’ career aspirations and interest in technology. *Research in Science and Technological Education*, 33(3), 366-386.

Berg, A.-J., & Lie, M. (1995). Feminism and Constructivism: Do Artifacts Have Gender? *Science, Technology, & Human Values*, 20(3), 332–351. <https://doi.org/10.1177/016224399502000304>

Billington, B., Britsch, B., Karl, R., Carter, S., Freese, J., & Regalla, L. (2014). SciGirls Seven: How to engage girls in STEM. Retrieved from http://www.scigirlsconnect.org/wp-content/uploads/2016/07/ScigirlsSeven_Print.pdf 29 April 2019

Brickhouse, N. W. (2001). Embodying science: A feminist perspective on learning. *Journal of Research in Science Teaching*, 38, 282–295. doi:10.1002/1098-2736(200103)38:3<282::aid-tea1006>3.0.co;2-0

Bryman, A. (2016). *Social research methods* (5th edition). Oxford: Oxford University Press.

Cheryan, S., Master, A., & Meltzoff, A. N. (2015). Cultural stereotypes as gatekeepers: increasing girls' interest in computer science and engineering by diversifying stereotypes. *Frontiers in psychology*, 6, 49. doi:10.3389/fpsyg.2015.00049

Denner, J., & Werner, L. (2007). Computer Programming in Middle School: How Pairs Respond to Challenges. *Journal of Educational Computing Research*, 37(2), 131–150. <https://doi.org/10.2190/12T6-41L2-6765-G3T2>

Elo, S. and Kyngäs, H. (2008), The qualitative content analysis process. *Journal of Advanced Nursing*, 62: 107-115. doi:[10.1111/j.1365-2648.2007.04569.x](https://doi.org/10.1111/j.1365-2648.2007.04569.x)

Emerson, R., Fretz, R. & Shaw, L. (2001). Participant observation and fieldnotes. In P. Atkinson, A. Coffey & S. Delamont, *Handbook of Ethnography* (pp. 352-368). SAGE Publications Ltd. doi: 10.4135/9781848608337.n24

Emerson, K. T. U., & Murphy, M. C. (2015). A Company I Can Trust? Organizational Lay Theories Moderate Stereotype Threat for Women. *Personality and Social Psychology Bulletin*, 41(2), 295–307. <https://doi.org/10.1177/0146167214564969>

Fox, M.J. (2011). Prototype theory: An alternative concept theory for categorizing sex and gender? In Smiraglia, R.P. (Ed.), *Proceedings from North American Symposium on Knowledge Organization, Vol. 3.* (pp. 151-159). Toronto, Canada.

Given, L. M. (Ed.) (2008). *The SAGE encyclopedia of qualitative research methods*. Thousand Oaks, CA: SAGE Publications, Inc. doi: 10.4135/9781412963909

Hogg, M., Terry, D., & White, K. (1995). A Tale of Two Theories: A Critical Comparison of Identity Theory with Social Identity Theory. *Social Psychology Quarterly*, 58(4), 255-269. Retrieved from <http://www.jstor.org/stable/2787127>

Hussénus, A., Andersson, K., Gullberg, A. & Scantlebury, K. (2013). Ignoring Half the Sky : A Feminist Critique of Science Education's Knowledge Society. *Science Education for Diversity: Theory and Practice.* (pp. 301-315). Rotterdam: Springer Netherlands. 10.1007/978-94-007-4563-6_14

Kim, A. Y., Sinatra, G. M., & Seyranian, V. (2018). Developing a STEM Identity Among Young Women: A Social Identity Perspective. *Review of Educational Research*, 88(4), 589–625. <https://doi.org/10.3102/0034654318779957>

Knopke, V. (2015). *Factors that encourage and facilitate female students to participate and engage in technology education*. Diss. Nathan: Griffith University

Sanders, J. (2005). *Gender and technology in education: A research review*. Retrieved from <http://www.josanders.com/pdf/gendertech0705.pdf>

Swedish Research Council. (2002). *Forskningsetiska principer inom humanistisk-samhällsvetenskaplig forskning*. Stockholm: Swedish Research Council.

Swedish Schools Inspectorate, (2014). *Teknik – gör det osynliga synligt*. (2014:4). Retrieved from <https://www.skolinspektionen.se/globalassets/publikationssok/granskningsrapporter/kvalitetsgranskningar/2014/teknik/kvalgr-teknik-slutrapport.pdf>

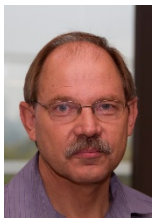
Turja, L., Endepohls-Ulpe, M., & Chatoney, M. (2009). A conceptual framework for developing the curriculum and delivery of technology education in early childhood. *International Journal of Technology and Design Education*, 19, 353–365.

Turner, John C. (1991). *Social influence*. Milton Keynes, [England] : Open University Press

Virtanen, S., Räikkönen, E., & Ikonen, P. (2015). Gender-Based Motivational Differences in Technology Education. *International Journal of Technology and Design Education*, 25(2), 197-211. <http://dx.doi.org.e.bibl.liu.se/10.1007/s10798-014-9278-8>.

Technology Students' attitudes towards STEM and interest in STEM careers: A South African perspective.

Francois Van As



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

ABSTRACT

In South Africa technical schools are specialised schools where all Grade/Year 10-12 students are enrolled for a technology subject of specialisation as well as Engineering Graphics and Design. Languages, mathematics and science are also compulsory subjects for these students (RSA, 2015). The aim of these schools is thus to broadly orientate students for vocations in technology and engineering. These students might have opted for these schools to receive a vocational-orientated education. In most of the developed countries there is currently a drive towards science, technology, engineering, and mathematics (STEM) education (Ritz & Fan, 2015). However, we do not know what the Grade/Year 9 students' attitudes towards the STEM subjects as well as interest in possible technology and engineering-related careers are. The purpose of the research was to determine technology students' attitudes towards the STEM subjects as well as interest in possible STEM careers. The research questions that underpinned this research were: (1) What are technology students' attitudes towards the STEM subjects? (2) What are technology students' interest towards careers in STEM? As a theoretical framework, the researcher addresses several viewpoints concerning the construct of attitudes toward technology, such as definitions of attitude, and fundamental reasons for measuring students' attitudes (Ankiewicz, 2016). Krapp and Prenzel (2011) regarded both attitudes and interest as motivational variables. The sample that participated in the study was 60 Grade/Year 9 students from a technical high school. A Likert scale questionnaire was used and selected descriptive and inferential statistics applied to identify main factors that probably contributed to the measured findings. The best predictors of the sub-dimension attitudes towards engineering and technology was the factor attitudes towards engineering followed by attitudes towards technology. With respect to the second sub-dimension namely, attitudes towards mathematics and science, the best predictor was attitudes towards science while positive attitudes towards STEM careers was the second best predictor.

Key words: Technology students, technical high school, STEM subjects, attitudes

INTRODUCTION AND THE CONTEXT OF THE STUDY

In the South African school context the subjects Science, Technology and Mathematics are still mainly taught in silo mode. Generally engineering is not part of junior high school. According to Williams (2011) and De Vries (2018), engineering is part of the broader field of technology. In order to meet the challenges of the 21st century, it is imperative to develop a broader and more coordinated strategy at school level in the teaching of science, technology, engineering and mathematics (STEM). According to Bybee (2010) these strategies should

“include all the STEM disciplines and address the need for greater diversity in the STEM professions, for a workforce with deep technical and personal skills, and for a STEM-literate citizenry prepared to address the grand challenges of the 21st century.”

Bybee (2010) further emphasised that true STEM education should increase students' understanding of how things work and improve their use of technologies. Students should also be introduced to engineering as it is directly involved in problem solving and innovation. Given its economic importance to society, students should learn about engineering and develop some of the skills and abilities associated with the design process.

In South Africa technical schools are specialised schools where all Grade/Year 10-12 (Senior high school) students are enrolled for a technology subject of specialisation, namely civil technology or electrical technology or mechanical technology as well as engineering graphics and design. Languages, mathematics and science are also compulsory subjects for these students (RSA, 2015). The aim of these schools is to broadly orientate students for vocations in technology and engineering. In the junior high school (Grade/Year 7-9) nine compulsory subjects are offered of which mathematics, natural sciences and technology are included (DBE, 2011). At the end of junior high school students' have to choose one of the technology subjects of specialisation as mentioned above. It is expected that technology education will provide students with some experience to help them to make career-oriented subject choices at the end of Grade/Year 9 (DBE, 2011).

These students might have opted for these schools to receive a vocational-orientated education. In most of the developed countries there is currently a drive towards STEM education (Ritz & Fan, 2015). However, we do not know what the Grade/Year 9 students' attitudes towards the STEM subjects as well as interest in possible technology and engineering-related careers are. The purpose of the research was to determine technology students' attitudes towards the STEM subjects as well as interest in possible STEM careers. The research questions that underpinned this research were:

- (1) What are technology students' attitudes towards the STEM subjects?
- (2) What are technology students' interest towards careers in STEM?

THEORETICAL FRAMEWORK

Within technology, knowledge from the other STEM subjects is incorporated in order to solve technological problems creatively. In this study the researcher is interested in measuring technology students' attitudes towards the STEM subjects, thus shifting the focus towards

STEM education. According to literature (Ankiewicz, 2018), the traditional approach towards student attitudes should address cognitive, affective and behavioral aspects. An attitude towards a concept such as technology is based on a person's beliefs about it (cognitive component) and is associated with emotional reactions (affective component). The stimulation of these reactions results in decisions to engage in behavior (behavioural component), such as choosing to take a technology course (Ankiewicz, 2018).

In STEM education, as in technology education the following reasons are offered to describe why learners' attitudes towards technology are considered important (Ankiewicz, 2018, p. 582/3):

“Students' attitudes have a major impact on career choices, courses of study, and subject fields in school. Students' attitudes towards technology play a significant role in alleviating anticipated shortages for technology within the labour market. Students' attitudes towards technology may be used to predict their achievement. Knowledge of students' attitudes towards technology enables curriculum developers, course designers, and teachers to better assist students in learning technology.”

Apart from determining technology students' attitudes towards the STEM subjects the researcher also investigates their interest towards careers in STEM. Ankiewicz (2019) notes that 'interest' and 'careers' were part of the six subscales in the PATT-Netherlands instrument that measured affective components of pupils' attitudes. The PATT-USA instrument had 'general interest' as one of two scales used to measure pupils' attitudes. Krapp and Prenzel (2011) regarded both attitudes and interest as motivational variables. Because of its focus on specific content the concept of interest seemed to be appropriate to understand tendencies of students to engage in certain themes or contexts - or withdraw from them. It is thus reasonable that studies on attitudes towards science and technology grasp the concept of interest (Krapp and Prenzel, 2011). According to the researchers, an interest represents a specific and distinguished relationship between a person and an object which can refer to concrete things, a topic, a subject-matter or an abstract idea. The interest relation to an object is characterised by certain cognitive and affective components of which the most important characteristics refer to an individual's values and feelings (Krapp and Prenzel, 2011).

RESEARCH DESIGN AND METHODOLOGY

A quantitative, descriptive research approach was followed by describing technology students' attitudes towards STEM and interest in STEM careers. Convenience sampling was used because the research focuses on a specific group of students who might provide useful information for answering the research questions (Creswell 2005). The group of students involved were 60 Grade/Year 9 technology students' in their final junior secondary phase at a South African technical high school. The reason for choosing this group is because they are at the brink of making their final subject choices for their senior secondary phase.

The data-collection instrument was a survey consisting of participants' biographical information and 61 Likert-scaled items with a 1-5 point Likert scale (1 = Disagree strongly and 5 = Agree strongly) based on the instrument to Assess Attitudes towards Science, Technology, Engineering, and Mathematics (STEM) of Guzey, Harwell & Moore (2014); pilot study items of students' attitudes towards STEM of Mahoney (2010); and Instruments for Assessing Interest in STEM Content and Careers of Tyler-Wood, Knezek & Christensen (2010). This paper only reports on the Likert-scaled items which focus on attitudes towards STEM.

The data bases consisted of 60 completed questionnaires. The information was captured on a Microsoft Excel worksheet and cleaned up to be used in analysis. The tests for validity, reliability and normality were applied using the Statistical Package for the Social Sciences (SPSS, version 25). Spearman's rho, a non-parametric statistical technique, was carried out to calculate the correlation coefficients between the second order factors (FB2.1 and FB2.2) and its component first-order factors.

FINDINGS AND DISCUSSION

The researcher made use of the Measure of Sampling Adequacy (MSA) in SPSS to remove items one at a time and then to view the Kaiser-Meyer-Olkin (KMO) value again. The rule of thumb used was that if the MSA value for an item was <0.50 then it should be removed. This procedure was cumbersome as the researcher had to remove 20 items, one at a time, and this left 41 items out of the 61.

A second-order KMO of 0.829 and Bartlett's sphericity value of $p=0.000$ indicated that a further reduction of the 10 first-order factors was plausible. This procedure resulted in two second-order factors which explained 60.05% of the variance present. The first of these factors was named "positive attitudes towards Engineering and Technology (FB2.1)" and it had a Cronbach reliability coefficient of 0.935 and contained 19 items (See Annexure A). The second second-order factor was named "positive attitudes towards Mathematics and Science (FB2.2)" and had a Cronbach reliability of 0.935 with 22 items in it (See Annexure B).

Discussion of the first second-order factor "Positive attitudes towards Engineering and Technology (FB2.1)"

The first-order factors and their items were as follows:

- Positive attitudes towards Engineering (FB1.1): Items involved were 49, 48, 51, 21, 52, 54, 22, 60 with an average loading of 0.765 and a Cronbach Alpha of 0.938 which is considered to be good.
- Positive attitudes towards Technology (FB1.3): Items involved were 59, 58, 56, 23, 55 with an average loading of 0.725 and a Cronbach Alpha of 0.884.
- Positive perceptions about Engineering (FB1.8): Items involved were 8, 7 with an average loading of 0.758 and a Cronbach Alpha of 0.850 despite having only two items in the factor.
- Positive perceptions about Technology (FB1.7): Items involved were 12, 11, 61, 53 with an average loading of 0.614 and a Cronbach reliability of 0.754.

The item with the highest mean score was B11 (I enjoy learning to use Technology) and the respondents agreed (4.37) with this item most strongly. The item with the lowest mean score was B8 (I am good at Engineering) with a mean of 3.00 indicating mostly an uncertainty. As engineering does not feature in the curriculum of Grade/Year 9 learners, their attitudes are probably largely based on the feelings and emotions based on what they have heard about the practice of Engineering. The distribution of data in the first second-order factor (FB2.1) is shown in Figure 1.

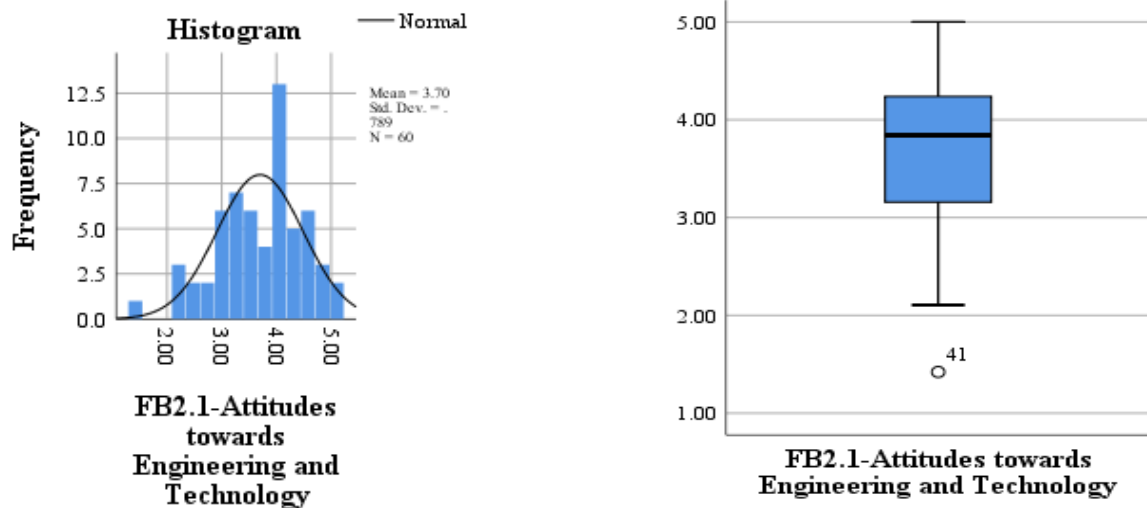


Figure 1: Histogram and boxplot of the first second-order factor (FB2.1) showing the distribution of data

The data distribution was negatively skew and non-parametric tests were used in further analysis of the data. The mean score was 3.70 and the median was 3.84. As the data were negatively skew this research made use of Spearman's rho to calculate the correlation coefficients between the first second-order factor (FB2.1) and its component first-order factors. Spearman's correlation coefficient between FB2.1 and its component factors are shown in Table 1.

The data in Table 1 show that it is only FB1.8 (Positive perceptions about Engineering) which has a correlation coefficient of <0.70 which shows good concurrent validity for most of underlying factors. Furthermore this researcher also calculated the discriminant validity (divergent validity) according to the formula suggested by Zait and Berteau (2011:219) namely:

$$AVE = \frac{\sum (\lambda)^2}{\sum (\lambda)^2 + \sum \epsilon}$$

where λ is the loading of the items on a factor and ϵ is the error of the measurement $(1-\lambda)^2$. In the case of FB2.1 (Attitudes towards Engineering and Technology) the value came to 0.84 which is larger than the correlations squared (0.60). Thus FB2.1 has both convergent validity and discriminant or divergent validity.

A linear regression where FB2.1 (Attitudes towards Engineering and Technology) was the dependent variable and FB1.1, FB1.3, FB1.8 and FB1.7 were the predictors indicated that FB1.1 (Positive attitudes towards Engineering) was the best predictor ($\beta=+0.572$). The second best predictor was FB1.3 (Positive attitudes towards Technology) ($\beta=+0.283$).

Table 1: Table showing the Spearman's correlation coefficient between the first second-order factor (FB2.1) and its component factors

			FB2.1	FB1.1	FB1.3	FB1.8	FB1.7	
Spearman's rho	FB2.1-Attitudes towards Engineering and Technology	Correlation Coefficient	1.000	.938**	.730**	.654**	.749**	
		Sig. (2-tailed)	.	.000	.000	.000	.000	
		N	60	60	60	60	60	
	FB1.1 - Positive attitudes towards Engineering	Correlation Coefficient	.938**	1.000	.558**	.601**	.586**	
		Sig. (2-tailed)	.000	.	.000	.000	.000	
		N	60	60	60	60	60	
	FB1.3 - Positive attitudes towards Technology	Correlation Coefficient	.730**	.558**	1.000	.295*	.580**	
		Sig. (2-tailed)	.000	.000	.	.022	.000	
		N	60	60	60	60	60	
	FB1.8 - Positive perceptions about Engineering	Correlation Coefficient	.654**	.601**	.295*	1.000	.396**	
		Sig. (2-tailed)	.000	.000	.022	.	.002	
		N	60	60	60	60	60	
	FB1.7 - Positive perceptions about Technology	Correlation Coefficient	.749**	.586**	.580**	.396**	1.000	
		Sig. (2-tailed)	.000	.000	.000	.002	.	
		N	60	60	60	60	60	
	**. Correlation is significant at the 0.01 level (2-tailed).							
	*. Correlation is significant at the 0.05 level (2-tailed).							

Discussion of the second of the second-order factors “Positive attitudes towards Mathematics and Science (FB2.2)”

The second second-order factor was named “positive attitudes towards Mathematics and Science” and had a Cronbach reliability of 0.935 with 25 items in it. The first-order factors and their items were as follows:

- Positive attitudes towards mathematics (FB1.4): Items involved were 40, 44, 42, 4 with an average loading of 0.83 on the factor and a Cronbach reliability of 0.900.
- Positive attitudes towards Science (FB1.2): Items involved were 36, 33, 1, 39, 37, 35, 34, 17, 29 with an average loading of 0.73 and a Cronbach reliability of 0.929.
- Positive beliefs about the value of STEM on society (FB1.6): Items involved were 32, 27, 26, 38 with an average loading of 0.63. It had a Cronbach reliability of 0.824.

- Positive attitudes about STEM careers (FB1.5): Items involved were 16, 50, 15, 25, 14 with an average loading of 0.600 and a Cronbach reliability of 0.859.

Item B27 (Science, technology, engineering, and mathematics make our lives better) and Item B26 (Having a job that involves science, mathematics, engineering, or technology would help me to be successful in life) had the highest mean score namely 4.37 indicating that the respondents agreed with these two items in the factor. Both these items could be said to have positive perceptions throughout most societies globally probably for their pragmatic value. Item B34 (I like to read about science, technology, engineering, and mathematics) had the lowest mean score namely 3.23 indicating a neutral attitude about this item. It is disconcerting to see that Grade/Year 9 students are neutral in their opinions about a liking for reading in the STEM subjects. However, there is no shortage of easily understandable information available on the internet about many issues concerning the value of these subjects to humans world-wide.

The distribution of data in the second of the second-order factor (FB2.2) is given in Figure 2.

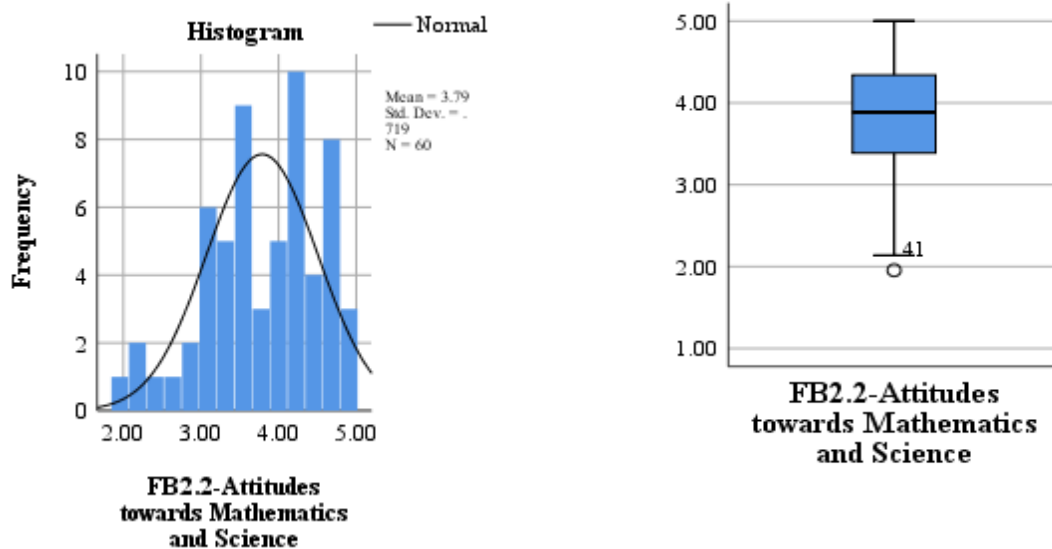


Figure 2: Histogram and boxplot of FB2.2 showing the distribution of data

The data can be seen to be slightly negatively skew with a mean of 3.79 and median of 3.88.

As the data were negatively skew this research made use of Spearman's rho to calculate the correlation coefficients. The Spearman correlation between the attitudes towards Mathematics and Science is given in Table 2.

Table 2: Table showing the Spearman's correlation coefficient between FB2.2 and its component factors

			FB2.2	FB1.4	FB1.2	FB1.6	FB1.5	
Spearman's rho	FB2.2-Attitudes towards Mathematics and Science	Correlation Coefficient	1.000	.666**	.890**	.773**	.774**	
		Sig. (2-tailed)	.	.000	.000	.000	.000	
		N	60	60	60	60	60	
	FB1.4 - Positive attitudes towards mathematics	Correlation Coefficient	.666**	1.000	.462**	.434**	.398**	
		Sig. (2-tailed)	.000	.	.000	.001	.002	
		N	60	60	60	60	60	
	FB1.2 - Positive attitudes towards Science	Correlation Coefficient	.890**	.462**	1.000	.596**	.545**	
		Sig. (2-tailed)	.000	.000	.	.000	.000	
		N	60	60	60	60	60	
	FB1.6 - Positive beliefs about the value of STEM in society	Correlation Coefficient	.773**	.434**	.596**	1.000	.581**	
		Sig. (2-tailed)	.000	.001	.000	.	.000	
		N	60	60	60	60	60	
	FB1.5 - Positive attitudes about STEM careers	Correlation Coefficient	.774**	.398**	.545**	.581**	1.000	
		Sig. (2-tailed)	.000	.002	.000	.000	.	
		N	60	60	60	60	60	
	**. Correlation is significant at the 0.01 level (2-tailed).							

The strongest correlation was between FB2.2 (Attitudes towards Mathematics and Science) and FB1.2 (Positive attitude towards Science). It is a common perception that Mathematics and Science are usually highly correlated. The lowest correlation was between FB1.4 and FB1.5 ($r=0.398$). A positive attitude towards mathematics and a positive attitude towards careers in STEM shows a low concurrent validity at <0.50 . The average loading of the underlying factors of FB2.2 was 0.700 which indicates concurrent validity. Using the same formula to calculate the divergent or discriminant validity or composite reliability a value of 0.81 resulted. The average squared correlations between the factors were 0.61 and factor FB2.2 also showed discriminant validity.

A linear regression where FB2.2 was the dependent variable and FB1.4, FB1.3, FB1.8 and FB1.7 were the predictors indicated that FB1.2 (Positive attitudes towards Science) was the best predictor ($\beta=+0.506$). The second best predictor was FB1.5 (Positive attitudes towards

STEM careers ($\beta=+0.289$). As FB2.2 has to do with attitudes towards mathematics and science one would expect that FB1.4 (Positive attitude towards mathematics) would be among the best predictors. However, it was only the third best predictor and although significant it could indicate problems regarding perceptions relative to mathematics which is a compulsory subject (as is science and technology) in technical schools. According to the Trends in International Mathematics and Science Studies (TIMSS) the average Grade/Year 9 South African student performs two to three grades lower than the average Grade/Year 8 student from other middle-income countries (Van der Merwe, 2018).

CONCLUSION

The attitudes of this sample of students towards STEM were built on two sub-dimensions namely one related to attitudes towards Engineering and Technology (FB2.1) and the other related to attitudes towards Mathematics and Science (FB2.2). The Pearson correlation between these two sub-dimensions was ($r=0.545$; $R^2=0.3003$) and hence the effect size is classified as large as 30.03% of the variance present between the two is accounted for (Field, 2018: 117). This effect is thus important and has substantive significance in that attitudes towards the one influences attitudes towards the other. Engineering is part of technology (Williams, 2011). Technology is practical and more informal and associated with fun (De Vries, 2018). On the contrary science and mathematics are theoretical, more formal and serious which in STEM education could be a threat to the fun in technology (De Vries, 2018). However, this does not indicate causality and although it seems logical that attitudes towards mathematics and science will lead to positive attitudes towards Engineering and Technology, this aspect needs further research as this relationship could also be a non-recursive one with a feedback loop from one sub-dimension to the other.

The best predictors of the sub-dimension attitude towards engineering and technology was the factor attitude towards engineering followed by attitude towards technology. With respect to the second sub-dimension namely, attitudes towards mathematics and science, the best predictor was attitude towards science while positive attitudes towards STEM careers was the second best predictor. One would possibly expect attitude towards mathematics to occupy the position of second best predictor but this was not the case.

It seems as if attitudes towards engineering, sciences and STEM careers are most important. This implies that technology teachers should focus on the development of students' attitudes towards engineering. Science teachers should focus on the development of students' attitudes towards science while science, technology and mathematics teachers should focus on the development of students' attitudes towards STEM careers.

A major limitation to this particular research project was the small number of respondents sampled and the large number of items in the questionnaire. The researcher used a small group of respondents as this will serve as a pilot study for future research into attitudes towards

STEM where more schools and respondents should participate. The questionnaire was found to exhibit reliability as well as concurrent and divergent validity.

Acknowledgements

I would like to express my sincere gratitude to Prof B Grobler for his assistance with the statistical analyses.

REFERENCE LIST

- Ankiewicz, P. (2018). Perceptions and Attitudes of Pupils towards Technology: in M.J. de Vries (ed.), *Handbook of Technology Education, Springer International Handbooks of Education*, DOI 10.1007/978-3-319—44687-5
- Ankiewicz, P. (2019). Perceptions and attitudes of pupils towards technology: In search of a rigorous theoretical framework. *International Journal of Technology and Design Education*, 29, 37-56.
- Bybee, R.W. (2010). What is STEM Education? *Science*, 329 (5995), 996.
- Creswell, J.W. (2005). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research*. Upper Saddle River, New Jersey: Pearson.
- Department of Basic Education (DBE). (2011). Curriculum and Assessment Policy Statement Grades R–9 (Schools): Technology. Pretoria: Department of Basic Education.
- De Vries, M.J. (2018). The T and E in STEM: From promise to practice. In M.J. de Vries, S. Fletcher, S. Kruse, P. Labudee, M. Lang, I. Mammes, C. Max, D. Münk, B. Nicholl, J. Strobel, & M. Winterbottom (Eds.) *Research in technology education*, 11-19. Waxmann.
- Field, A. (2018). *Discovering Statistics using IBM SPSS Statistics*. 5th ed. London: SAGE
- Guzey, S. S., Harwell, M., & Moore, T. (2014). Development of an Instrument to Assess Attitudes towards Science, Technology, Engineering, and Mathematics (STEM). *School Science and Mathematics*, 114(6), 271-279.
- Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education*, 33(1), 27–50.

Mahoney, M. P. (2010). Students' Attitudes towards STEM: Development of an Instrument for High School STEM-Based Programs. *Journal of Technology Studies*, 36(1), 24-34.

RSA. Government Gazette. (2015). Department of basic education. Approval of the amendments to the regulations pertaining to the national curriculum statements grades R-12. Vol. 605, 20 November 2015, No. 39435

Ritz, J.M. & Fan, S-C. (2015). STEM and technology education: international state-of-the-art. *International Journal of Technology and Design Education*, 25, 429-451.

Tyler-Wood, T., Knezek, G., & Christensen, R. (2010). Instruments for Assessing Interest in STEM Content and Careers. *Jl. Of Technology and Teacher Education*, 18(2), 341-363.

Van der Merwe, D. (2018). Aspects of academic language proficiency of intermediate phase teacher education students. *South African Journal of Childhood Education*, 8(1), a555. <https://doi.org/10.4102/sajce.v8i1.555>

Williams, P. J. (2011). STEM education: Proceed with caution. *Design and Technology Education: An International Journal*, 16(1), 26–35.

Zait, A. & Berteau, P.E. (2011). Methods of testing discriminant validity. *Management & Marketing*, Vol 1X, issue2/2011.

ANNEXURE A

Items in the factor positive attitudes towards Engineering and Technology (FB2.1)

FB2.1 - Items in the factor positive attitudes towards Engineering and Technology ($\alpha = 0.935$ for 19 items)			
Item	Description: Indicate your agreement or disagreement with each of the statements below:	Mean	SD
B49	To me engineering is fascinating (FB1.1)	3.40	1.32
B48	To me engineering is appealing.(FB1.1)	3.35	1.26
B51	To me engineering means a lot (FB1.1)	3.48	1.27
B21	I am interested in taking more classes that involve engineering (FB1.1)	3.47	1.43
B52	To me engineering is exciting (FB1.1)	3.58	1.27
B54	To me engineering is interesting (FB1.1)	3.43	1.25
B22	It is important to know engineering in order to get a good job (FB1.1)	3.12	1.52
B60	I care about developments in science, technology, engineering, and mathematics (FB1.1)	4.23	0.85
B59	To me technology is exciting (FB1.3)	3.95	1.10
B58	To me technology is interesting (FB1.3)	3.93	0.94
B56	To me technology means a lot (FB1.3)	3.97	0.99
B23	I am interested in taking more classes that involve technology (FB1.3)	3.77	1.09
B55	To me technology is appealing (FB1.3)	3.87	1.00
B8	I am good at engineering (FB1.8)	3.00	1.09
B7	I enjoy learning engineering (FB1.8)	3.45	1.21
B12	I am good at using technology (FB1.7)	4.07	0.99
B11	I enjoy learning to use technology (FB1.7)	4.37	0.94
B61	To me technology is fascinating(FB1.7)	3.78	1.15
B53	I believe there is a need for science, technology, engineering, and mathematics (FB1.7)	4.07	1.16
Average		3.70	1.15

ANNEXURE B

Items in the factor positive attitudes towards Mathematics and Science (FB2.2)

FB2.2 - Positive attitudes towards Mathematics and Science ($\alpha = 0.935$)			
Item	Description: Indicate your agreement or disagreement with each of the statements below according the scale provided	Mean	SD
B40	To me mathematics is interesting (FB1.4)	4.05	1.00
B44	To me mathematics is fascinating (FB1.4)	3.82	1.05
B42	To me mathematics is appealing (FB1.4)	3.83	1.17
B4	I enjoy learning mathematics (FB1.4)	3.90	1.10
B36	To me science is exciting (FB1.2)	3.45	1.25
B33	To me science is fascinating (FB1.2)	3.37	1.06
B1	I enjoy learning science (FB1.2)	3.45	0.95
B39	To me science is interesting (FB1.2)	3.57	1.14
B37	To me science means a lot (FB1.2)	3.40	1.17
B35	To me science is appealing (FB1.2)	3.37	1.06
B34	I like to read about science, technology, engineering, and mathematics (FB1.2)	3.23	1.11
B17	I am interested in taking more classes that involve science (FB1.2)	3.68	1.32
B29	To me a career in science, technology, engineering, or mathematics is appealing (FB1.2)	3.92	0.96
B32	Science, technology, engineering, and mathematics are very important in life (FB1.6)	4.13	0.96
B27	Science, technology, engineering, and mathematics make our lives better (FB1.6)	4.23	1.06
B26	Having a job that involves science, mathematics, engineering, or technology would help me to be successful in life (FB1.6)	4.23	1.08
B38	To me science, technology, engineering, and mathematics is valuable (FB1.6)	3.83	1.12
B16	To me a career in science, technology, engineering, or mathematics is exciting (FB1.5).	3.73	1.13
B50	I intend to further develop my abilities in science, technology, engineering, and mathematics (FB1.5)	4.15	1.05
B15	To me a career in science, technology, engineering, or mathematics is interesting (FB1.5)	4.08	0.96
B25	I would like to have a job that involves science, mathematics, engineering, or technology (FB1.5)	3.78	1.46
B14	To me a career in science, technology, engineering, or mathematics means a lot (F1.5)	4.10	1.10
Average		3.79	1.10

Technology teachers' attitude towards technology: An investigation of Chinese high school general technology teachers.

Meidan Xu, P. John Williams



Meidan Xu
Nanjing Normal University
China
xumeidan_njnu@qq.com



P John Williams
Curtin University
Australia
pjohn.williams@curtin.edu.au

ABSTRACT

Through exploratory factor analysis and confirmatory factor analysis, the validity, reliability and robustness of technology teachers' attitude towards technology (TTATT) scale was evidenced. This study measured 140 Chinese high school general technology teachers' professional attitudes towards technology, and compared attitude differences on a range of factors. Using descriptive statistics, it found that Chinese high school general technology teachers are positive about teaching technology; they thought technology and technology curriculum are important and relevant to daily life, they enjoyed in teaching technology, and had confidence in teaching. However, they had difficulties and gender stereotypes while teaching technology, were worried about the teaching of technology curriculum, and found it hard to find teaching support. The independent t-test revealed that there was a significant gender difference in teachers' professional attitudes towards technology, but no differences between pre-service degrees. Results of a one-way ANOVA revealed that technology teachers' attitudes differed according to their teaching experience, their pre-service major areas of study, and in-service training frequencies.

Keywords attitude, individual difference, technology education, technology teachers

Introduction

Technology education in China, also called general technology education, is not limited to a single curriculum but rather encompasses several curriculum, including design technology, material technology, processing technology, traditional technology, electronic technology, control technology, building technology, agricultural technology, cooking technology and clothing technology (Gu, 2015), which is similar to Design and Technology Curriculum in western countries. The current research on the Chinese general technology curriculum is mainly about curriculum content, teaching design, students' performance in making, design, inventing and so on, less about the general technology teachers, and particularly their professional attitudes towards technology.

Teachers' professional attitude, as a factor contributing to teachers' professional development, has a significant influence on the effects of teaching (Aalderen-Smeets & Molen, 2015). However, technology teachers' professional attitude towards technology has not been valued by Chinese technology education researchers, and only in some countries, such as the USA and Greece, teachers' attitude towards technology had received some attention, but these are older studies in 1989 and 1991 (Bame, 1989; Mottier, Raat, & De Vries, 1991; Androulidakis, 1991), no new research has been done.

From previous studies in other disciplines we know that teachers' positive attitudes have a significant impact on teaching behaviour (Aalderen-Smeets & Molen, 2015), teaching practices (Giovannelli, 2003), teaching frequencies, experience, and pedagogical content knowledge (Rohaam & Jochems, 2012). In contrast, if teachers have a negative attitude, they are more likely to have lower self-efficacy and confidence, avoid discussing and teaching courses, and negatively impact students' learning attitudes and achievements (Aalderen-Smeets & Molen, 2015; Rohaan, Taconis, & Jochems, 2010; Osborne, Simon, & Collins, 2003). Aalderen-Smeets and Molen (2015) conducted an experimental pretest-posttest control group study to demonstrate that attitude-focused training courses are more effective in improving attitudes towards teaching science, self-efficacy beliefs and enjoyment, than merely being engaged in science content-focused teaching. Therefore, clarifying the components of teachers' professional attitude towards technology, investigating individual differences, those are essential prerequisites to improving technology teachers' professional attitudes towards technology.

Technology teachers' professional attitude

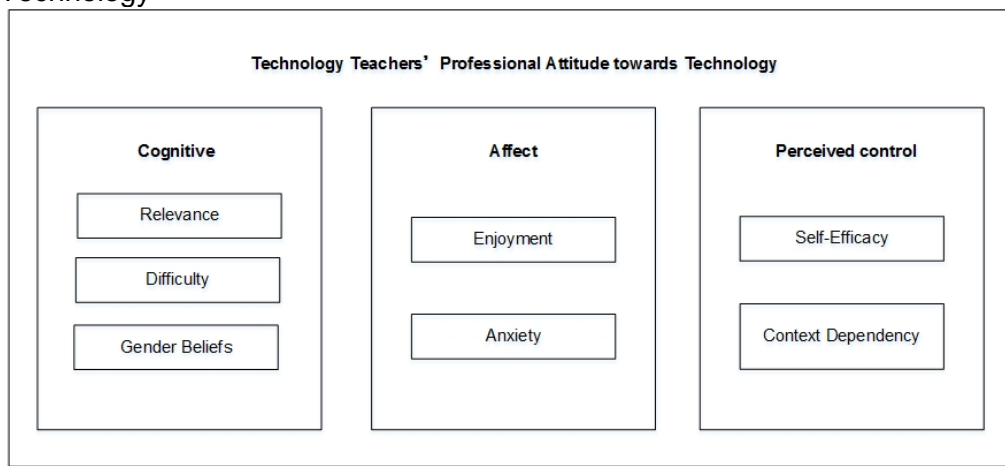
Bame (1989) investigated 71 teachers from 18 schools in Virginia using a PATT-USA Teachers' Questionnaire, this questionnaire contained five demographic questions, and 60 items which were grouped under nine scales, which were not elaborated. Androulidakis (1991) investigated 251 Greek teachers' attitude towards technology, it was found that only two meaningful factors of the questionnaire could be extracted through factor analysis, they were labelled (a) "the importance of technology and the necessity for a course to be taught in high schools" and (b) "interest in technology", and only eleven items were meaningful. Therefore, the theoretical framework for a Chinese general technology teachers' professional attitude scale should be developed from other studies.

A widely accepted theoretical framework of teachers' attitude was developed by Aalderen-Smeets, Molen and Asma (2012), consisting of a tripartite model of attitude based on Bandura's social cognitive theory (Bandura, 1997) and Ford's motivation systems theory (Ford, 1992). Aalderen-Smeets et al. (2012) thought that attitude can be divided into two types: professional attitude and personal attitude, two attitudes are different and represent two underlying objects of attitude separately. But both two attitudes consist of three identical dimensions: cognitive, affect and perceived control, and each dimension has the same

subcomponents, only the test items' content statements are different.

In the theoretical framework of Alderen-Smeets et al. (2012), the cognitive dimension refers to individual thoughts and beliefs towards teaching a curriculum and includes three subcomponents: relevance, difficulty and gender beliefs. The affect dimension refers to bad or good emotions and feelings related to a curriculum, and contains two subcomponents: enjoyment and anxiety. The perceived control dimension contains two internal and external subcomponents towards teachers' perceptions of controlling a curriculum, they are self-efficacy and context dependency. This study adopted the above theoretical framework to study Chinese high school general technology teachers' professional attitudes towards technology, as summarized in Figure 1.

Figure 1. Theoretical Framework of Technology Teachers' Professional Attitude towards Technology



The individual factors in teachers' professional attitude

Individual factors in teachers' professional attitude have been widely discussed by researchers in different disciplines. According to Ambusaidi and Al-Farei (2017), Omani female science teachers had more positive attitudes towards teaching science than male teachers, especially in the dimensions of managing hands-on science. Cebesoy and Oztekin (2017) found that female teachers have more favourable attitudes towards the use of genetic information than male teachers. However, some studies on teachers' attitude found no gender difference towards teaching astronomy (Ucar & Demircioglu, 2011), computer use (Teo, 2008), English grammar (Polat, 2017) and integrated STEM (Thibaut, Knipprath, Dehaene, & Depaepe, 2017). In view of the possible differences, this study accepts gender as a possible differentiating factor that influences Chinese high school general technology teachers' professional attitude.

In studies of teachers' attitudes in other disciplines, we know that teachers' degrees had no significant effect on mathematical teaching beliefs and attitudes (Ren & Smith, 2017), there were no influences of special education training on teachers' attitudes towards inclusive education while taking the level of education as a moderating factor (Orakci, Aktan, Toraman, & Çevik, 2016), and that teachers with master's degrees had no significant effect on STEM education attitudes (Thibaut et al., 2017). However, Polat (2017) found that teachers with PhD degrees had a more positive attitude towards grammar methodology teaching than other teachers with lower degrees, and the teachers with master's degrees had a more positive attitude towards grammar error correction than teachers with other degrees. Therefore, teachers' degrees were considered in this study, and refer to whether the teachers have a bachelor or master degree.

Polat (2017) revealed that teachers who have eight to 15 years' work experience have significantly more positive attitudes towards grammar teaching than teachers with less than seven years, or more than 15 years' work experience. Other studies presented a negative correlation between teachers' attitude and teaching experience, for example experienced teachers possessed negative attitudes towards gene therapy (Cebesoy & Oztekin, 2017), and had passive attitude towards implementing cooperative learning (Saborit, Fernández-Río, Estrada, Méndez-Giménez, & Alonso, 2016). The teachers with more than 20 years' teaching experience are more negative in teaching integrated STEM (Thibaut et al., 2017). In addition, there are also some studies to show that teaching experience is unrelated to professional attitude in Mathematics (Ren & Smith, 2017). According to the above literature review, teaching experience should also be taken into consideration in this study. The Chinese high school general technology curriculum has been established for less than 15 years, so this item has four options: less than one year, one to five years, six to 10 years, and 11 to 15 years.

To be a high school general technology teacher in China, a high school teacher qualification certification, a pass in the prescribed examination of general technology curriculum and meeting the recruitment needs of schools, are needed to be a formal high school general technology teacher, no matter what major you studied in university. Teachers' pre-service major subject as a demographic variable was referred in the study of Androulidakis (1991). Therefore, an investigation of the attitude differences between technology teachers' majors could be beneficial to this study.

Hartell, Gumaelius, and Svärth (2014) investigated differences in technology teachers' self-efficacy on assessment between teachers with subject-specific teacher training in technology education and teachers without such training, and found that there are significant differences between two groups' confidence and self-efficacy on assessment. Alkharusi, Kazem, and Al-Musawai (2011) compared pre-service teachers who had a teaching practicum with those who have no teaching practicum, and they found that pre-service teachers with a teaching practicum had more positive attitudes toward educational measurement. Thus, training frequencies seems to be an important factor to indicate teachers' professional attitudes.

Overall, gender, degree, teaching experience, the major area of study, and in-service training frequency were considered as factors in this study related to attitude.

Aim

There are no detailed and comprehensive instruments of technology teachers' attitude towards technology that were discovered in this literature review, and Chinese high school general technology teachers' professional attitudes have not been measured. Therefore, the aim of this study was to develop an instrument to investigate Chinese high school general technology teachers' professional attitudes, and analyze the individual differences of seven subcomponents in order to suggest ways to improve teachers' attitudes. The aim is addressed by answering the following research questions:

- (1) What is the Chinese high school general technology teachers' professional attitude towards technology?
- (2) What are the individual differences between the seven subcomponents?
- (3) How can Chinese high school general technology teachers' professional attitudes be improved?

Method

There were two steps in conducting this research: (1) Exploratory factor analysis, reliability analysis and confirmatory factor analysis were used to demonstrate the instrument is reliable

and valid. (2) Using descriptive statistics and analysis of variance to reveal the perceptions of technology teachers' attitude, and explore the individual differences in the seven subcomponents of professional attitude in light of five individual characteristics.

Sample

A sample of 140 teachers were recruited from QQ group, which is an instant messaging software like MSN, which connects all high school general technology teachers from 31 provinces, a total of about 350 teachers. The questionnaire was distributed through a web link to the QQ group, and filled out by the teachers who wanted to be involved. Teachers could withdraw anytime while answering this questionnaire. Table 1 provides the sample profile of this study.

Table 1
Sample profile

Items	Categories	N (%)
Gender	Male	95 (67.9%)
	Female	45 (32.1%)
Degree	Bachelor	121 (86.4%)
	Master	19 (13.6%)
Teaching experience	less than one year	7 (5%)
	1-5 years	45 (32.1%)
	6-10 years	53 (37.9%)
	11-15 years	35 (25%)
Major relevance	completely irrelevant	26 (18.6%)
	irrelevant	34 (24.3%)
	little relevant	35 (25.0%)
	relevant	41 (29.3%)
	completely relevant	4 (2.9%)
Training frequency	none	7 (5.0%)
	1-2 events	60 (42.9%)
	3-4 events	41 (29.3%)
	5-6 events	9 (6.4%)
	more than 6 events	23 (16.4%)
TOTAL		140 (100%)

Instrument Development

In the studies by Androulidakis (1991) and Bame (1990), the three factors of importance, interest, and gender beliefs were determined to influence teachers' attitude towards technology. These could be combined with the theoretical framework of science teachers' attitude proposed by Alderen-Smeets et al. (2012), and a theoretical framework for measuring technology teachers' professional attitude was developed, which was the basis for the Technology Teachers' Attitude towards Technology (TTATT) instrument. The TTATT instrument consists of two parts; the first part is about technology teachers' demographic characteristics, which includes five items. The second part is to measure technology teachers' attitude, which uses a six-point Likert-type scale (strongly disagree to strongly agree) to elicit teachers' attitude tendencies about teaching technology. It has seven subcomponents and 23 items in total, each subcomponent contains at least three items, as shown in Appendix 1.

Instrument Validation

Reliability Analysis and Factor Analyses

The instrument's reliability is measured by Cronbach's alpha coefficient ($\alpha = 0.66$), and the sub-components all exceed 0.6. The α value of relevance is 0.74, difficulty is 0.83, gender belief is 0.80, enjoyment is 0.63, anxiety is 0.76, self-efficacy is 0.75, and context dependency is 0.84. If all α values are higher than 0.6, this indicates the instrument is reliable (Wu, 2010).

Through exploratory factor analysis (EFA), this study produced a Kaiser-Meyer-Olkin (KMO) value of 0.757 and Bartlett's test of sphericity ($\chi^2 = 1368.74$, $p < 0.001$), which indicates the data is suitable for EFA. Using direct oblimin rotation, seven factors with an eigenvalue greater than one were extracted. The underlying dimensions analyzed are consistent with the theoretical framework, and the factor loading of every item exceeds 0.4, which indicates the instrument has a good structural validity (Can, 2014).

Using confirmatory factor analysis (CFA) to test the instrument's factorial and convergent validity, the fit indices meet the requirements of a qualified instrument (Wu, 2010), and the standardized estimates loading on item-factor (Kline, 2005) are close to or above 0.5 and at a significant level ($p < 0.001$), which indicates that the seven subcomponents in this model are an acceptable fit.

Results

Descriptive Analysis

The scores in Table 2 are the percentages of mean scores on the seven subcomponents. It can be seen that the scores of Relevance, Enjoyment and Self-efficacy are 82.53%, 81.9% and 75.12% respectively, which shows that Chinese high school general teachers attach importance to the relevance of the general technology curriculum, feel happy in teaching technology and have a positive sense of self-efficacy in teaching. However, the scores of Difficulty, Gender beliefs, Anxiety, and Context dependency are 50.91%, 57.5%, 58.97%, and 50.63%, which shows that teachers believe teaching is a little difficult, they have gender bias, feel anxious and worried, and feel there is not enough support for their teaching. The total mean score percentage of teachers' professional attitude is rather high (66.54%), which indicates that teachers have a general positive attitude towards teaching general technology.

Table 2

Descriptive statistics of technology teachers' professional attitude

Subcomponents	Mean (%)
Relevance	82.53 (%)
Difficulty	50.91 (%)
Gender beliefs	57.5 (%)
Enjoyment	81.9 (%)
Anxiety	58.97 (%)
Self-efficacy	75.12 (%)
Context dependency	50.63 (%)
professional attitude	66.54 (%)

Analysis of Variance

Standard scores are also called zscores, which is a value that is not affected by an original unit of measurement, and is used to compare scores measured on different scales. The scores of the seven subcomponents are standardized to zscores.

1. Gender differences in technology teachers' professional attitude

An independent t-test was used to analyze gender differences in technology teachers'

professional attitude. There were no significant gender differences in teachers' professional attitude in six subcomponents (relevance, difficulty, enjoyment, anxiety, self-efficacy, context dependence) (Sig >0.05), except for gender beliefs. Female technology teachers have less gender bias than male teachers, believing that females and males are not different in learning and teaching ability, and both can perform well in technology education, but male technology teachers believe there is a difference.

2. Degree differences in technology teachers' professional attitude

To present the influence on attitude of the degree technology teachers hold, an independent t-test was conducted. The findings show that there are no differences in teachers' professional attitude and seven subcomponents (Sig >0.05) regardless of the level of degree the teacher holds.

3. Teaching experience differences in technology teachers' professional attitude

A one-way ANOVA was conducted to explore the effect of years of teaching on technology teachers' professional attitude. The result shows that there are some differences in anxiety, self-efficacy and professional attitude (Sig <0.05). The data indicates that: (1) teachers with teaching experience between 1-5 years are more anxious and worried about teaching general technology than others who have teaching experience between 6-10 years and 11-15 years; (2) teachers with teaching experience between 1-5 years have a lower sense of self-efficacy in teaching general technology than others with more teaching experience; (3) teachers with less than 1 year teaching experience are more likely to have a negative attitude towards teaching general technology than those with more teaching experience.

4. Pre-service major area of study differences in technology teachers' professional attitude

A one-way ANOVA was conducted to explore the attitude differences based on the pre-service major area of study. The result shows that there are some differences in the relevance, difficulty, and anxiety subcomponents, and total professional attitude (Sig <0.05). It seems that: (1) technology teachers whose major is relevant to the general technology curriculum thought the curriculum is more important than those majors less relevant to teaching curriculum; (2) technology teachers whose major is completely irrelevant to the general technology curriculum thought teaching general technology is more difficult than those with relevant majors; (3) technology teachers whose major is completely irrelevant to the general technology curriculum are more anxious and worried about teaching general technology than those with more relevant majors; (4) technology teachers whose major is completely irrelevant to the general technology curriculum have a more negative attitude towards teaching than with more relevant majors.

5. In-service training frequency differences in technology teachers' professional attitude

A one-way ANOVA was conducted to explore the influence of in-service training frequency on teachers' attitude. The result shows that there are some differences in enjoyment, self-efficacy, context dependency, and total professional attitude (Sig <0.05). Specifically: (1) teachers with no in-service training or 1-2 training events in the last three years get less enjoyment from teaching than those who had more in-service training; (2) teachers with 1-2 training events in the last three years have a lower sense of self-efficacy in teaching general technology than others with more in-service training; (3) teachers with 1-2 training events in the last three years get less external and teaching support than others with more training; (4) teachers with no training or 1-2 training events in the last three years are more likely to develop a negative professional attitude.

Discussion and Conclusion

The framework of the TTATT instrument is derived from the Dimensions of Attitudes towards Science and Technology questionnaire (DAST) proposed by Asma, Molen and Alderen-Smeets (2011), and both adopted the theoretical framework of Alderen-Smeets, Molen and

Asma (2012). This study advanced the construct of technology teachers' professional attitude, which refined the interview content about technology teachers' attitude in the study of Asma et al. (2011), listed more comprehensive and clearer measurement constructs than the study of Nordlöf, Höst and Hallström (2017), then compiled the testing items based on previous studies. Statistics were used to demonstrate the TTATT instrument is reliable, valid and qualified to measure Chinese technology teachers' attitude towards technology.

Chinese high school general technology teachers' professional attitude is rather positive, especially in relevance, enjoyment and self-efficacy. This result is the same as the findings of Nordlöf et al. (2017), only 25.6% of Swedish compulsory technology teachers had negative attitude towards teaching technology, and they considered technology to be an important subject. But the reason Chinese and Swedish technology teachers have high self-efficacy in teaching technology is different, in that Swedish technology education was often taught at a low level, thus facilitating self-efficacy. But Chinese high school technology teachers have confidence in teaching and understanding technology.

However, some Chinese technology teachers have difficulty teaching, are worried and anxious, and experience a lack of external support and few teaching resources. This finding is consistent with other studies, the technology teachers in New Zealand were also lack of equipment and facing insufficient funding (Jones & Bronwen, 2004; Almutari, 2009). But, unlike Bame's (1989) research, US teachers thought that the external support for middle school technology curriculum is strong.

Male technology teachers are more likely to have a gender bias than female teachers. Teachers' gender stereotype may not only occur in technology teaching, but also in mathematics teaching (Li, 1999) and STEM education (Kraker-Pauw, Wesel, Verwijmeren, Denessen, & Krabbendam, 2016). In this study, male teachers had higher expectations for boys than girls, and thought they are better than female teachers in technology teaching. This findings is definitely different from Bame's (1989) finding, US teachers did not view technology as being male dominated. It can be assumed that gender bias may be from social division of labour in Chinese traditional culture, and then reflected in technology education.

Technology teachers' professional attitudes towards technology are influenced by the length of teaching experience, the relevance of pre-service majors, and the frequencies of in-service training. Moreover, teaching experience may influence their affect and perceived control towards technology, individual pre-service major areas will influence cognition and affect towards technology, and training frequencies will influence affect and perceived control towards technology.

Implications

Based on above findings, some implications for improving technology teachers' professional attitude and shortening individual differences are discussed.

- Teachers should be encouraged to take part in professional development, which focuses on the difficulties they face in understanding the contents of general technology curriculum.
- School administrators should give technology teachers more support.
- Teachers should be conscious of gender bias, regard boys and girls as equals, give more positive psychological support to girls, and provide examples of female technologists as role models.
- Due to a lack of teaching experience, it is easy for teachers to be anxious and worried about teaching technology. A response is to encourage these teachers to cooperate and collaborate with experienced and expert technology teachers.
- For technology teachers whose majors are not related to general technology, subject-specific professional development should be undertaken.

Limitations

Some items' content is specific to Chinese high school general technology curriculum, thus translation and back-translation of the TTATT instrument is essential before using it in other countries. Moreover, unlike Mathematics and English teachers, who have a higher social profile, the numbers of high school general technology teachers are not large, thus the sample is small. Further study will increase the sample size of technology teachers in different countries or regions, and develop a universal TTATT instrument.

References

- Aalderen-Smeets, S. I. V., & Molen, J. H. W. V. D. (2015). Improving primary teachers' attitudes toward science by attitude-focused professional development. *Journal of Research in Science Teaching*, 52(5), 710-734.
- Aalderen-Smeets, S. I. V., Molen, J. H. W. V. D., & Asma, L. J. F. (2012). Primary teachers' attitudes toward science: a new theoretical framework. *Science Education*, 96(1), 158–182.
- Almutari, A. (2009). *Teachers' Perceptions of Technology and Technology Education, Years 7 to 10*. Thesis, Auckland University of Technology.
- Alkharusi, H., Kazem, A. M., & Al-Musawai, A. (2011). Knowledge, skills, and attitudes of preservice and inservice teachers in educational measurement. *Asia-Pacific Journal of Teacher Education*, 39(2), 113-123.
- Ambusaidi, A., & Al-Farei, K. (2017). Investigating Omani science teachers' attitudes towards teaching science: the role of gender and teaching experiences. *International Journal of Science and Mathematics Education*, 15(1), 71-88.
- Androulidakis, S. (1991). Greek teachers' attitudes towards technology, A first approach. In PATT 5 conference proceedings, (pp. 219–223). Eindhoven, the Netherlands.
- Asma, L.J. F., Molen, J. W. V. D., & Aalderen-Smeets, S. I. V. (2011). Primary teachers' attitudes towards science and technology. In de Vries, M. J., Kuelen, H. V., Peters, S., & Molen, J. W. V. D. (Eds.), *Professional Development for Primary Teachers in Science and Technology* (pp. 89-105). The Netherlands: Sense Publishers.
- Bame, E. A. (1989). What do American teachers think of technology. In *PATT 4 conference proceedings* (pp. 320-323). Eindhoven, the Netherlands.
- Bandura, A. (1997). *Self-efficacy: The Exercise of Control*. New York: Freeman.
- Can, A. (2014). *Quantitative Data Analysis in the Scientific Research Process with SPSS*. Ankara: PegemA Publishing.
- Cebesoy, U. B., & Oztekin, C. (2017). Genetics literacy: insights from science teachers' knowledge, attitude, and teaching perceptions. *International Journal of Science and Mathematics Education*, 16(7), 1247-1268.
- Ford, M. E. (1992). *Motivating Humans: Goals, Emotions, and Personal Agency Beliefs*. Thousand Oaks, CA, US: Sage Publications, Inc.
- Giovannelli, M. (2003). Relationship between reflective disposition toward teaching and effective teaching. *Journal of Educational Research*, 96(5), 293-309.
- Gu, J. J. (2015). Analysis and reflection on the achievements and problems of general technology curriculum experiment in high school in China during the past 10 years. *Educational Research and experiment*, (2), 29-36.
- Hartell, E., Gumaelius, L., & Svårdh, J. (2014). Investigating technology teachers' self-efficacy on assessment. *International Journal of Technology and Design Education*, 25(3), 1-17.
- Jones, A., Ann, H., & Bronwen, C. (2004). New Zealand teachers' experiences in implementing the technology curriculum. *International Journal of Technology & Design Education*, 14(2), 101-119.
- Kline, R. B. (2005). *Principle and Practice of Structural Equation Modeling* (Second Edition). New York: The Guilford Press.
- Kraker-Pauw, E. D., Wesel, F. V., Verwijmeren, T., Denessen, E., Krabbendam, L. Are teacher

- beliefs gender-related? *Learning and Individual Differences*, 51, 333-340.
- Li, Q. (1999). Teachers' beliefs and gender differences in mathematics: a review. *Educational Research*, 41(1), 63-76.
- Mottier, I., Raat, J.H., & De Vries, M.J. (Eds.). (1991). Research on the PATT 5 conference. In PATT 5 conference proceedings, Volume 1, (pp. 29–36). Eindhoven, the Netherlands.
- Nordlöf, C., Höst, G. E., & Hallström, J. (2017). Swedish technology teachers' attitudes to their subject and its teaching. *Research in Science & Technological Education*, 35(2), 195-214.
- 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.
- Orakci, S., Aktan, O., Toraman, Ç., & Çevik, H. (2016). The influence of gender and special education training on attitudes towards inclusion. *International Journal of Instruction*, 9(2), 1694-1609.
- Polat, M. (2017). Teachers' attitudes towards teaching English grammar: a scale development study. *International Journal of Instruction*, 10(4), 379-398.
- Ren, L., & Smith, W. M. (2017). Teacher characteristics and contextual factors: links to early primary teachers' mathematical beliefs and attitudes. *Journal of Mathematics Teacher Education*, 21(4), 1-30.
- Rohaan, E. J., & Jochems, W. M. G. (2012). Analysing teacher knowledge for technology education in primary schools. *International Journal of Technology and Design Education*, 22(3), 271-280.
- Rohaan, E. J., Taconis, R., & Jochems, W. M. G. (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(1), 15-26.
- Saborit, J. A. P., Fernández-Río, J., Estrada, J. A. C., Méndez-Giménez, A., & Alonso, D. M. (2016). Teachers' attitude and perception towards cooperative learning implementation: influence of continuing training. *Teaching and Teacher Education*, 59, 438-445.
- Teo, T. (2008). Pre-service teachers' attitudes towards computer use: a singapore survey. *Australasian Journal of Educational Technology*, 24(4), 413-424.
- Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2017). How school context and personal factors relate to teachers' attitudes toward teaching integrated STEM. *International Journal of Technology and Design Education*, 28(3), 1-21.
- Ucar, S., & Demircioglu, T. (2011). Changes in preservice teacher attitudes toward astronomy within a semester-long astronomy instruction and four-year-long teacher training programme. *Journal of Science Education and Technology*, 20(1), 65-73.
- Wu, M. R. (2010). *Structural Equation Model: Operation and Application of AMOS*. Chongqing: Chongqing University Press.

Appendix 1. Test Items

Relevance

1. It is important to teach general technology at the high School level.
2. General technology is not as important as Math and English.
3. Knowledge of general technology is important for students and their future.
4. The content of general technology course has little to do with daily life situation.

Difficulty

5. I find it difficult to explain to my students about the technological theory hidden in technological product.
6. It is difficult to develop students' technological literacy.
7. It is difficult to cultivate students' technological thinking and action.

Gender beliefs

8. Boys are more capable of doing technological jobs than girls.
9. Male teachers enjoy teaching general technology in High school more than female teachers.
10. Male teachers are better at designing interesting technological experiments than female

teachers.

Enjoyment

- 11. Preparing general technology lessons is a boring process.
- 12. I am happy to share my technological knowledge with students.
- 13. I have no desire to change my existing teaching methods.

Anxiety

- 14. I worried about whether I can accomplish teaching goals of every class.
- 15. Designing good technological activities makes me anxious.
- 16. I feel worried when I cannot explain the contents of general technology course clearly.

Self-efficacy

- 17. I can bring many points of view into teaching.
- 18. I know the steps necessary to teach technological concepts effectively.
- 19. I understand technological content well enough to be effective in teaching high school general technology course.
- 20. When teaching general technology, I usually welcome students' questions.

Context dependency

- 21. At my school, there are no good teaching materials for technology education.
- 22. At my school, there are no well-established workshops for general technology education.
- 23. The management of my school wants to develop the subject of general technology.

Facets of Creativity evidenced Through a Design and Technology Summer Programme.

Daniel Zarb, Sarah Pulé



Daniel Zarb
University of Malta
Malta
daniel.zarb@um.edu.mt



Sarah Pulé
University of Malta
Malta
sarah.pule@um.edu.mt

ABSTRACT

This research explores whether a systematically developed summer school D&T programme could aid children in attaining creativity whilst gaining psychomotor skills and a richer spectrum of D&T related technological vocabulary. This research involved three participating bodies: a) the researcher b) a Playworker, c) two participating student groups. Qualitative methods were used in analysing data collected through observations, questionnaires, literature, photographic/recorded evidence and interviews. The study identifies key aspects, which enhance the students' skills in psychomotor, creativity and lingual acquisition.

Keywords: Design and Technology, creativity, technical jargon, psychomotor skills

Introduction

Through the Maltese primary school years, students are taught three main core competences: Literacy, Numeracy and E-literacy. Through these core competences, learners at the primary level of schooling develop their basic educational foundation in communicative and analytical skills (Directorate for Quality and Standards in Education, 2009). Providing early learners with technological skills could support and compliment the core competences in intellectual and cognitive development. The subject of Design and Technology provides unique competencies not present in the mentioned core competencies. These are deemed to be highly beneficial for young learners in the technological world of today. The presence of D&T in primary schools, could enable learners to "...combine practical and technological skills with creative thinking to design and make products and systems that meet human needs" (Northgate High School, 2017).

Research Question

The research question tackled in this research was: Could a systematically developed D&T programme assist students to think more creatively?

Literature

Maltese D&T Setting

In the Maltese educational setting, D&T aims at educating learners through Materials, Electronic Systems and Graphical Design (MATSEC, 2020). It is offered as a compulsory subject in all state Middle schools, and as a choice subject in all Government schools, and in most private and church schools (Directorate for Quality and Standards in Education, 2015). The subject's curriculum aims for Maltese learners to enhance creativity and problem-solving skills, correctly select appropriate resources with proper use of equipment, and effectively communicate with each other and different audiences according to the situation in context (Directorate for Quality and Standards in Education, 2015).

Creativity

Creativity involves an elusive, complex concept that is defined in an educational context as an imaginative activity fashioned so as to produce outcomes that are both original and of value (National Advisory Committee on Creative and Cultural Education (NACCCE), 1999). Creativity benefits a learner's self-development, aiding in holistic lifelong education (Directorate for Quality and Standards in Education, 2015). De Bono adds that creativity is viewed as the "means bringing into being something that was not there before" (DeBono, 1992, as cited in Johnston, 2002). Through the idea generation process the learner relates to a scenario for which perception, thoughts and actions are manipulated through the creative process (Warr, 2007). The processes of subdivision and categorization of ideas and assumptions may result in better understanding of a problem (Bruce A. Marlowe). Thus learners are more likely to produce original ideas out of bundles of knowledge (Gabora, 2002, Santanen et al., 2002, as cited in Warr, 2007). The design aspect of the D&T activities should be an ideal platform to target the systematic development of creative thinking.

The Creative Process

The creative process may be viewed as the generation of an original idea, created from existing knowledge in conjunction with experience and memory up till the moment of task initiation (Gabora, 2002, Santanen et al, 2002 as cited in Warr, 2007). Boden explored how creativity is the end result of the linking of knowledge bundles through a process of association, in turn creating a bundle of knowledge, known within a person's conceptual space (Warr, 2007). Creativity can be viewed in three different strategies, measuring the participant's skill sets as derived from the activities. According to Barlex, these three strategies include: a) conceptual combination (two separate bodies of knowledge merged into a resultant one,

subjective to the participant's interpretation), b) analogy (transfer of a concept from one entity to another) and c) metaphor (An understanding or idea translated into literacy) (Barlex, 2011).

Psychomotor skills

Psychomotor abilities are aspects of a person's development credited to physical functions, including actions and reflex movements (Djilas, 2008). This may be seen in the fine movements a person does to satisfy a physical task. This includes muscle flexing in terms of motion, speed and repetition, achieved through motor-neuron information transmission (Djilas, 2008).

Technical Jargon

Throughout secondary educational schools, English language is taught within a curricular framework, as an educational and utilitarian subject. This system provides: a) students with communicative abilities, setting ways for knowledge transfer, b) a tailored way of understanding the needs of specific subjects (Strevens, 1972).

Such uses of English could be applied to the D&T context in Malta. 'Technical English' can be the appropriate language to use to correctly communicate and understanding certain D&T terminology (Fox-Turnbull, 2013). 'Technical English' uses the same grammar, structure and phonology as Standard English, however it is used as a utilitarian tool for describing any technical knowledge and process (Strevens, 1972).

Methodology

Qualitative Approach

Qualitative data was used as the means of gathering, organizing and interpreting knowledge. Data was collected through observations, questionnaires, literature, photographic/recorded evidence and interviews. Results were then analysed using comparative thematic analysis. Internal validity was addressed by having two Playworkers conducting the classes, one of whom was the researcher himself.

Participants

The study involved three participating bodies: a) the Researcher (male) (engaging in in-field activity initiation and data gathering as a Playworker himself), b) the Playworker (female)

(engaging in in-field activity initiation and data gathering), and c) two participating student groups; 8 students in Playworker’s classroom, and 10 students in the Researcher’s classroom; as shown in Figure 1.

Participating Playworker

The Playworker was given instructions for providing the class with the same activities to be done in the researcher’s own summer school class. Her role was to be both observational and evaluative. Her tasks involved noting student progress, design originality, enhancement in technical language through the natural use of the learnt words whilst in discussion, as well as careful manipulation of resources upon which the activities would be centered.

Participating Students

There were eighteen Year 5 participating students aged between eight and ten years. The Students were grouped according to Figure 1. The Year 5 group choice was influenced by the cognitive abilities present at that age group.

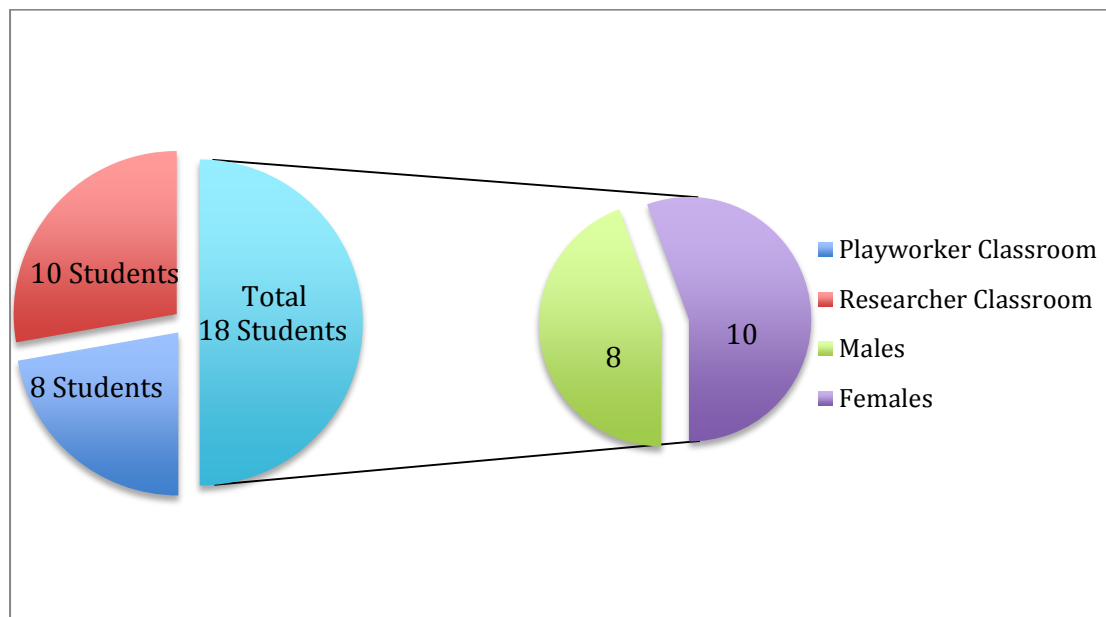


Figure 33: Participating Students

Activities

Various daily activities relating to D&T and to the summer school theme were presented to the Year 5 students. The activities served as the grounds for the active research to relate whether students were able to enhance creative, psychomotor and lingual acquisition skills through the presented activities. The activities were to be manufactured using stationery tools including:

pencils, pens, markers, rubbers, rulers, and scissors. Activities also included group discussions, through which the student's use of technical jargon was evaluated, at the end of each week. A few activity examples are shown as in Figures 2-5.

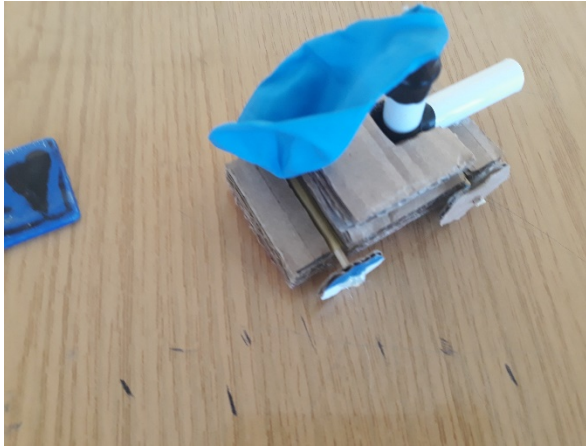


Figure 34: Balloon Propelled Vehicle Activity



Figure 35: Hydraulic Crane Activity

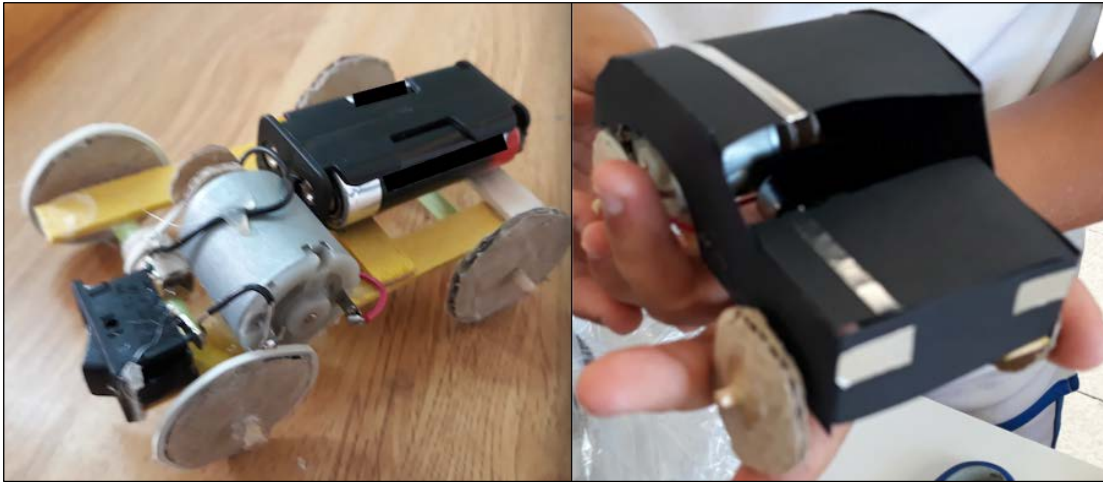


Figure 36: Electric Toy Car Activity

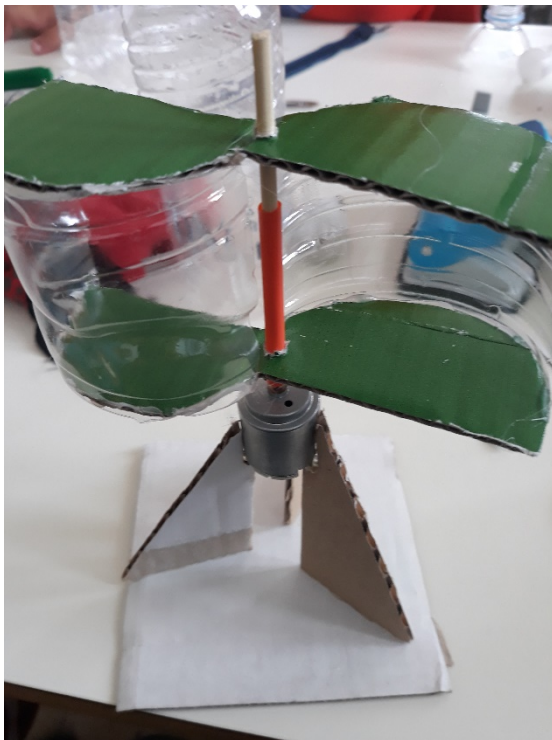


Figure 37: Wind Turbine Activity

Results and Discussion

Creativity through Psychomotor Achievement

The students' ability at using tools correctly was linked to the students' ability at selecting the right tools for the task. Students needed the correct tool handling techniques through a variety of tools to progress on to more demanding activities. A lack of stationery tool usage knowledge would only allow students to complete a limited number of activities. Throughout the six weeks, the students' psychomotor skills were noted as in Figure 6 and Figure 7.

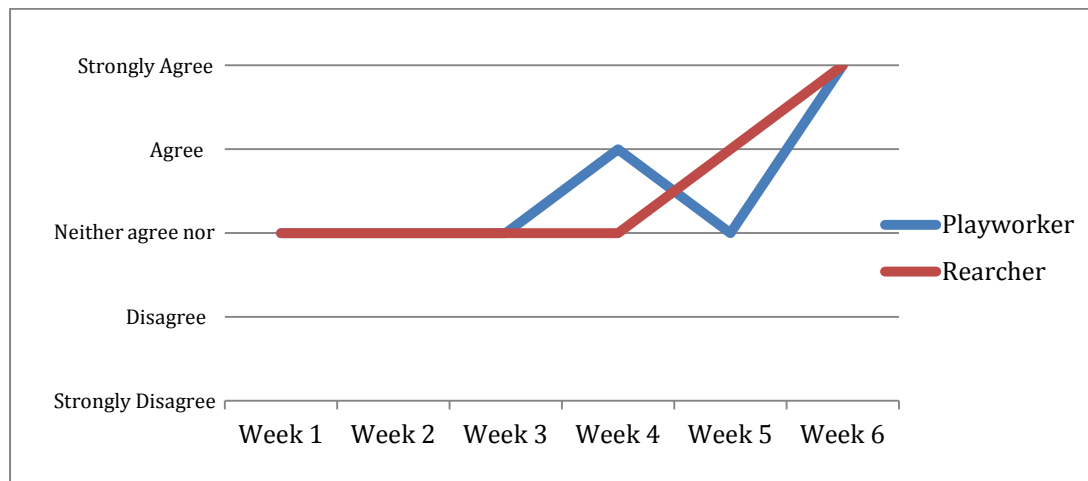


Figure 38: Perceptions of the students' ability to use stationery tools correctly

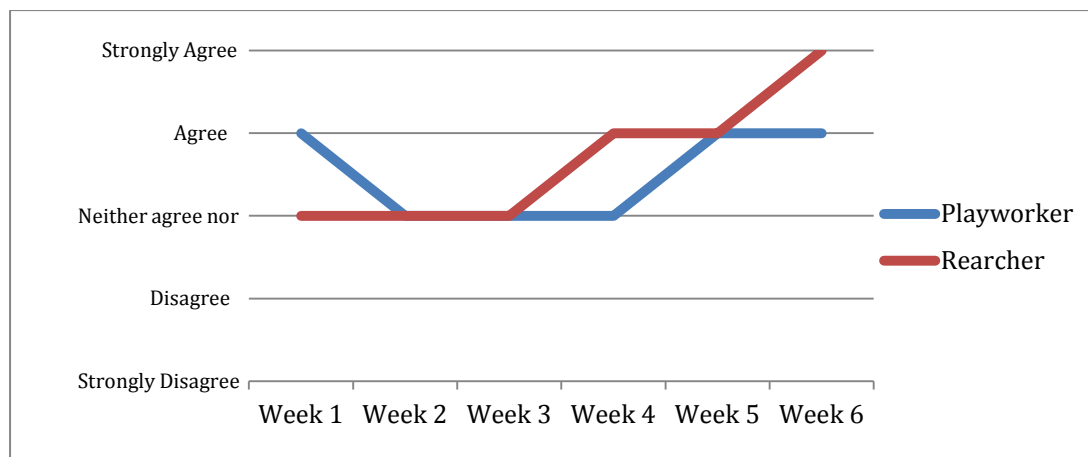


Figure 39: Perceptions of the students' ability to select the right stationery tools

The students' conceptualization abilities progressed through three levels of psychomotor progressions: a) low initial psychomotor abilities (weeks 1-3), b) medium psychomotor achievement (weeks 4-5), c) high psychomotor achievement (week 6).

a) Low initial psychomotor abilities

Initially students showed a low degree of tool handling abilities. Students used incorrect alternative tools due to a lack of correct tool handling abilities. This was initially noted in the students' efforts at cutting cardboard. Students cut cardboard using a ruler instead of scissors, producing undesired results. The Playworker also experienced such behavior in her class. She stated:

"I think that the most difficult part some students find is cutting... Even though I always keep reminding them of this method, the students still found difficulties... I start to worry wonder how the students could possibly find the task so difficult to fulfill."

b) Medium psychomotor achievement

The students' psychomotor abilities progressed after gaining experience though using various tools. This was required to complete the more demanding activities. At this stage the students were only comfortable at following the Playworkers' indicated tool selection and methods. Students believed that the indicated methods would lead to guaranteed, 'fail-safe' results. A 'fail-safe' result would be the standard result as briefed in the activity; satisfying the activity's situation in terms of function, form and aesthetics. This stage is represented in weeks 4-5 in Figure 6 and Figure 7. The students gained the necessary knowledge to further their psychomotor skills, gaining confidence in result manipulation through function, form and aesthetics.

c) High psychomotor achievement

After further practice, the students progressed in reasoning which tools would obtain the desired results. Students started making their own good tool choices and applying correct tool handling skills because they understood why the right tool gave better results. They became independent choosers and users of the right tools; Figure 8.

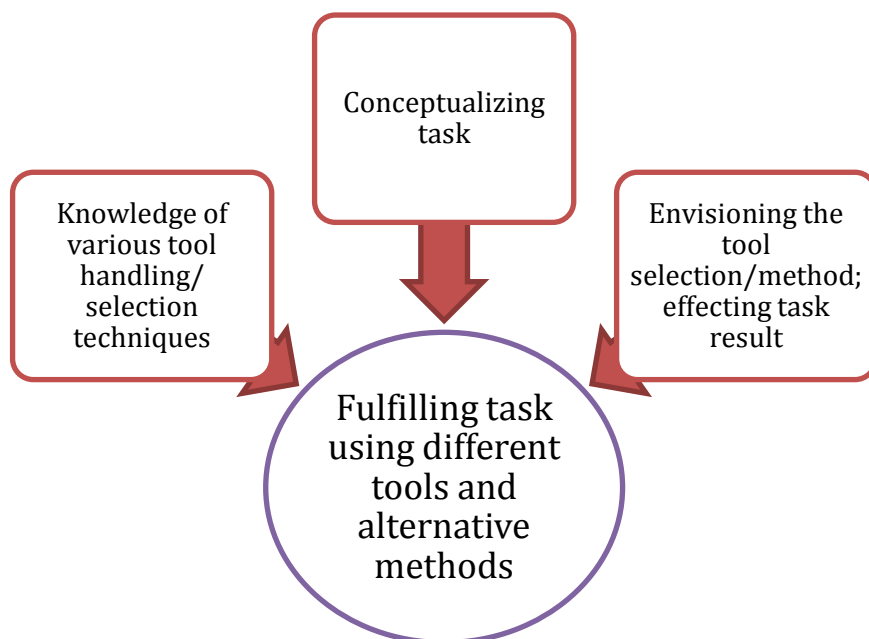


Figure 40: Skills associated with knowing how to use different tools

This process initially occurred during the Venice mask activity; shown in Figure 9. The students used a pin to punch various holes next to each other, later tearing along the perforated path. As scissors would also be correct yet would be time-consuming, producing less definitive cuts. This shows that students were engaging in the creative process via combining various bodies of knowledge in tool utilization. At that point, students started utilising resources as tools, including: string (tying and used as a compass alternative, pins (punching holes), cardboard (as stencils for tracing), kebab sticks (aligning multiple cardboard cut-outs through holes in the layering activity) and rubber bands (temporary binding solution).



Figure 41: Mask to which alternative stationery tools were first used

The manipulation of the activities' key aspects (function, form and aesthetics), led students to engage in risk taking. Sometimes, the students risked ending up with faulty or aesthetically displeasing results. Sticking to the activity instructions and guidance,

students would attain standard yet reliable results. Risk taking, showed the vast degree of the students' determination and creative levels, in attaining original results.

The students' psychomotor progression occurred due to the determination to translate their conceptualized result into physical outcomes. Students wanted to achieve this skill by copying correct alternative tool selection and handling methods used by other students. Experience was gained as a result of practice, allowing students to use their own tool choice and method for achieving their conceptualized result; Figure 10.

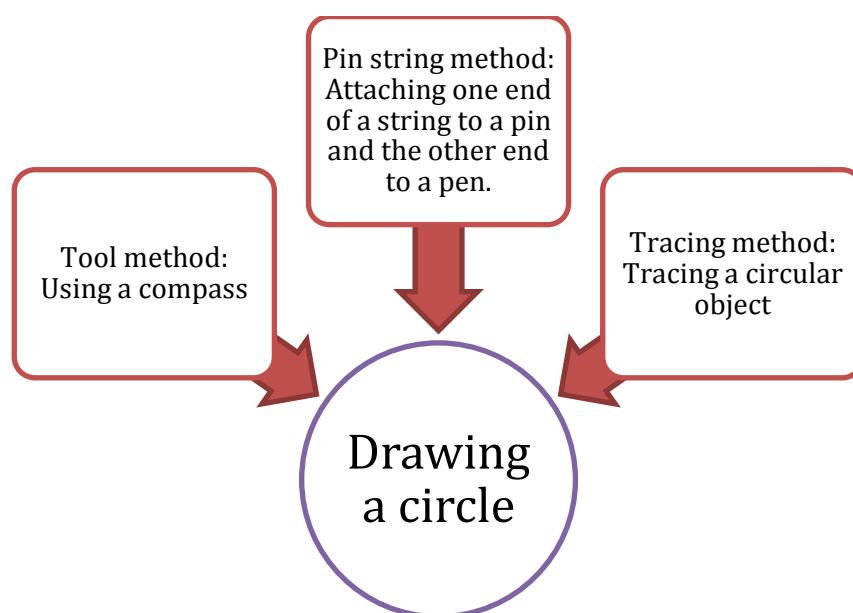


Figure 42: Tool Selection/ Handling method example

Learning to select the desired tools for the task resulted in enhanced conceptual ability. This was noted from the students' will to experiment in terms of result function, form and aesthetics. Both Playworker and researcher noticed that students wanted to engage in more challenging activities. This further enhanced the students' psychomotor and creative skills, improving in results whilst developing self-confidence.

Serializing Knowledge through Conceptual Ability

Figure 6 and Figure 7 show the students' sequential enhancement of psychomotor and conceptual abilities through activity engagement. This progression meant, that students related on-going activities with knowledge gained through previous tasks. Since activities increased in complexity, activity planning in terms of method and execution was necessary. This planning process occurred through idea and knowledge serializing. Students engaged in a) categorization of knowledge; relating the necessary information with activity execution b) sub-division of knowledge to obtain a plan of ideas for achieving the result; Figure 11.

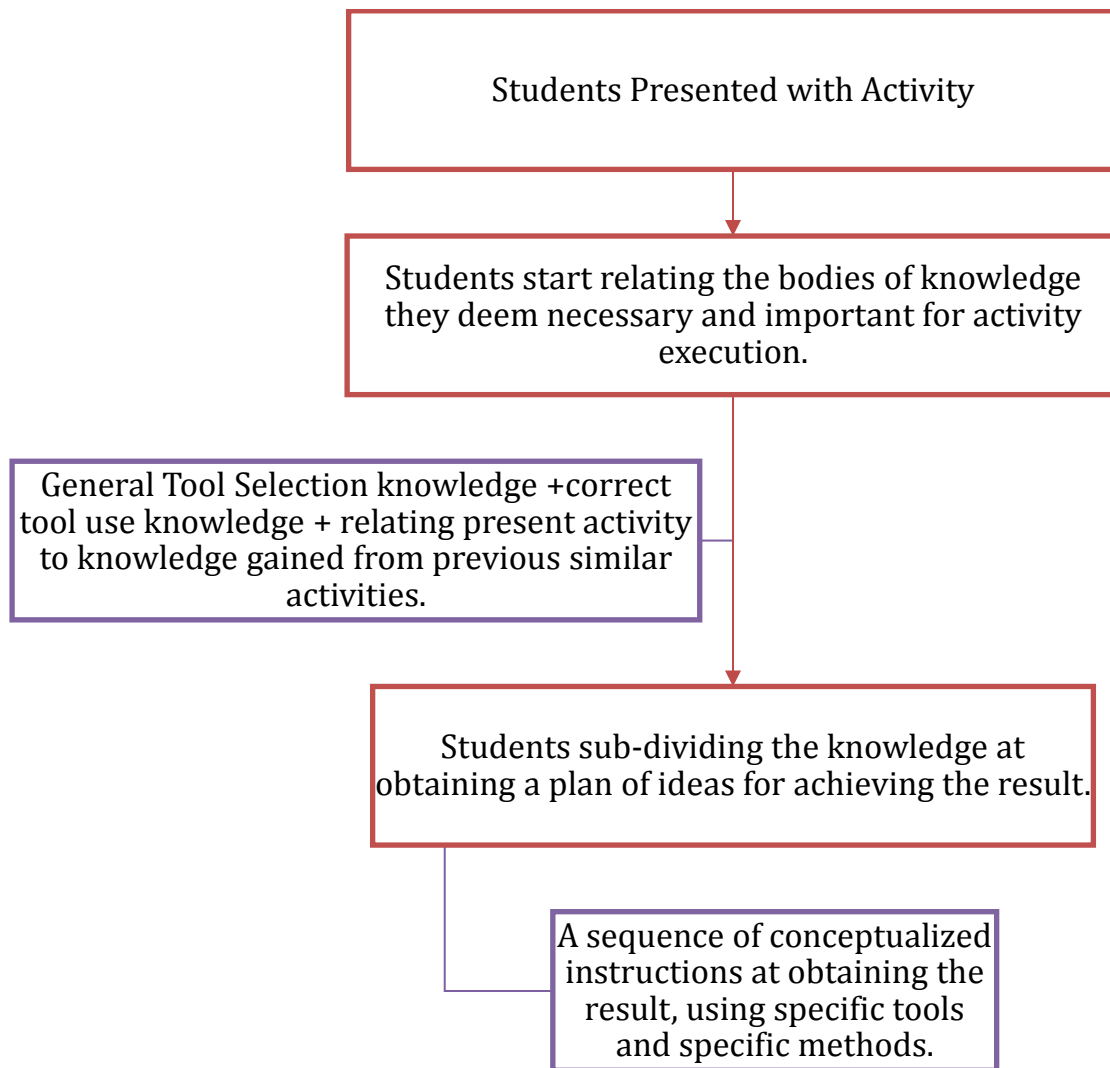


Figure 43: Serializing knowledge through Conceptual Ability

The pre-division and categorization of tool knowledge evidences activity conceptualization. Students were able to imagine the finished product, and process instructions through which the product could be achieved.

Enhancing the Creative Process through Technical Jargon

The Technical jargon used through the study, referred to technical objects or processes; Example: Bracket: L-shaped structure used for supporting a perpendicular joint, Momentum: an object's mass in motion. Students linked the technical jargon to task methods at which point the words were initially mentioned. This could be observed through a discussion about Bearings and Friction:

Researcher: Remember this car? (Researcher points and moves a balloon-propelled car on the desk, Figure 2). Can you all note that the wheels are turning? What did we use to make the wheels turn round?

Students: We used drinking straws, kebab sticks...
Researcher: Why did we use drinking straws and kebab sticks?
Students: So it would rotate freely without friction...
Researcher: What's the name of the device?
Students: ...no friction so, Bearing!

As a result, technical jargon was found to enhance the students' abilities at expressing themselves more clearly, through technical definitions and concepts. By expressing themselves, the students' showed that they were able to relate thoughts and ideas between two objects or concepts using logic and reasoning (Sowa J.F., 2003). The relationship between ideas and thoughts are seen in the mentioned Bearings and Friction discussion. Students were able to relate ideas and thought, through three sequential steps: a) activity with the manufacturing method, b) activity and manufacturing method (step a) with previously learnt technical jargon, c) activity, manufacturing method and previously learnt technical jargon (step b) with newly learnt technical jargon, shown in Figure 12. The relationship of one entity to another is in itself a creativity-enhancing strategy, known as 'analogy' (Barlex, 2011). The relationship process at each stage, enabled students to combine and build on their existing knowledge. The resultant knowledge set, led to define the newly learnt technical jargon in terms of concept and method. This process is itself a result of conceptual combination. This led students to enforce the newly presented jargon's definition through their own individual knowledge foundation.

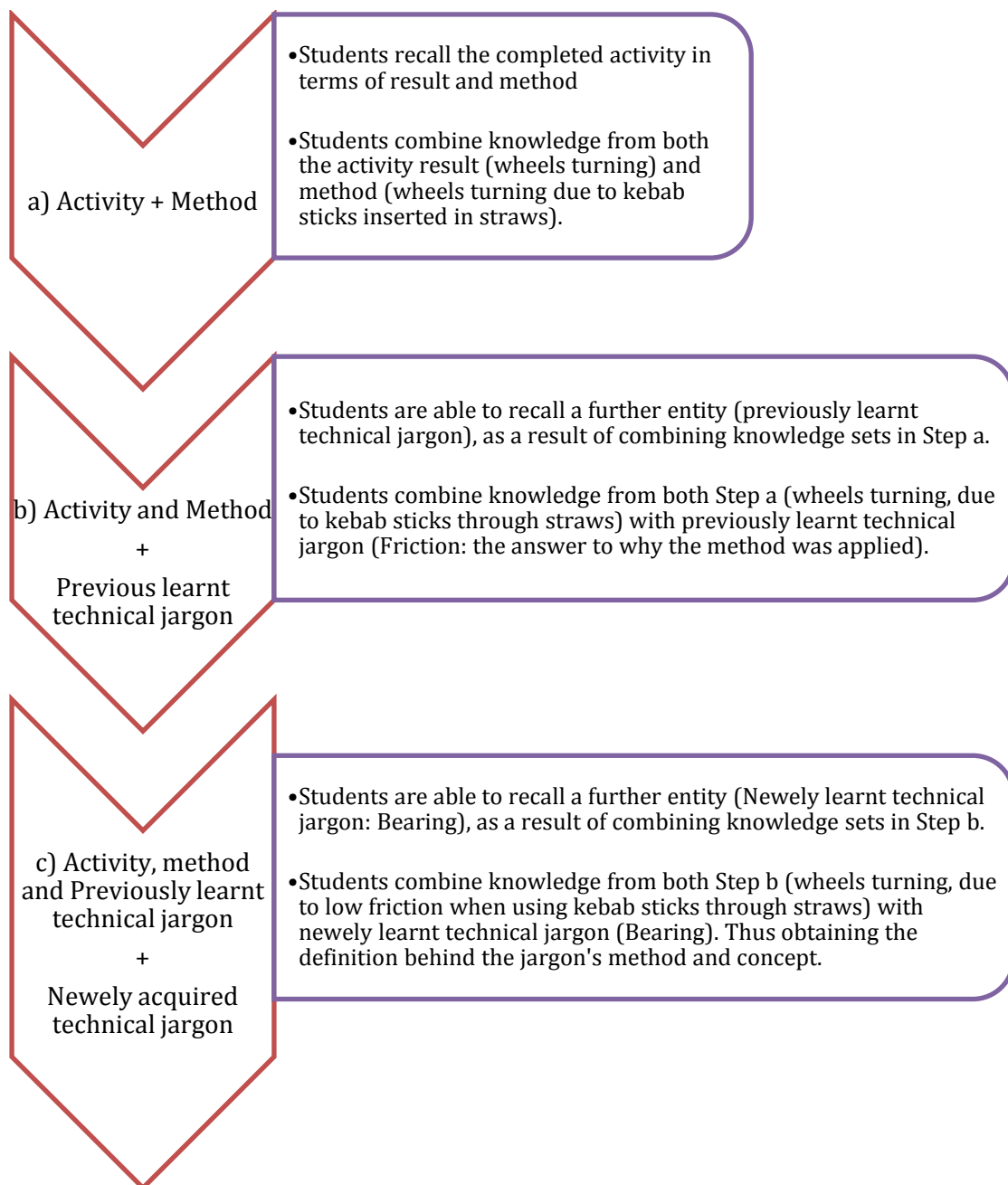


Figure 44: Conceptual Combination and Analogy resulting in Technical Jargon Acquisition

Respectively, this process enhanced the students' abilities to relate presented jargon to activity explanations; Figure 13.

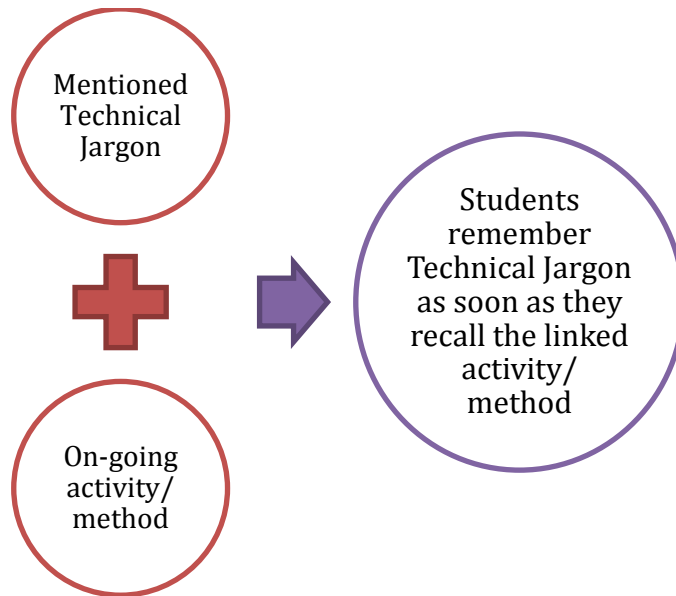


Figure 45: Students' ability to remember Technical Jargon

The students were able to learn the technical words related to the D&T activities' learning aims. If the technical words were new to the students, learning the words indicate that the activities are reaching their goals in teaching students new technical jargon; Figure 14.

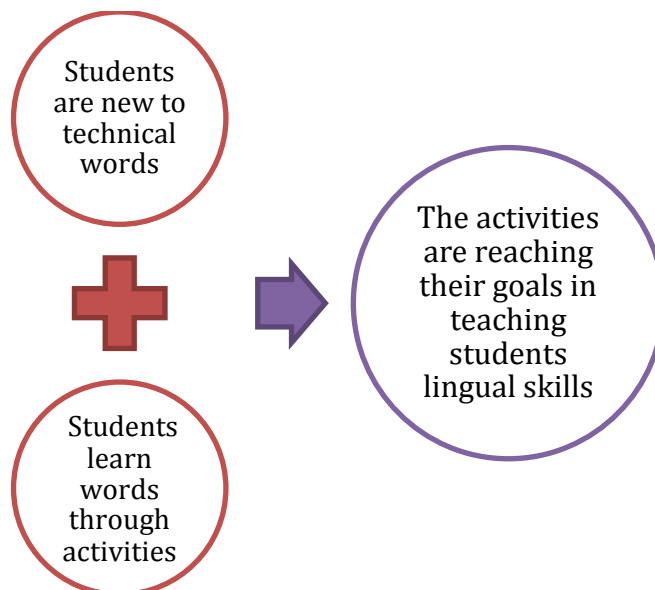


Figure 46: Goals reached by activities via teaching technical jargon

This could be observed through the relationship observed between Figure 15 and Figure 16.

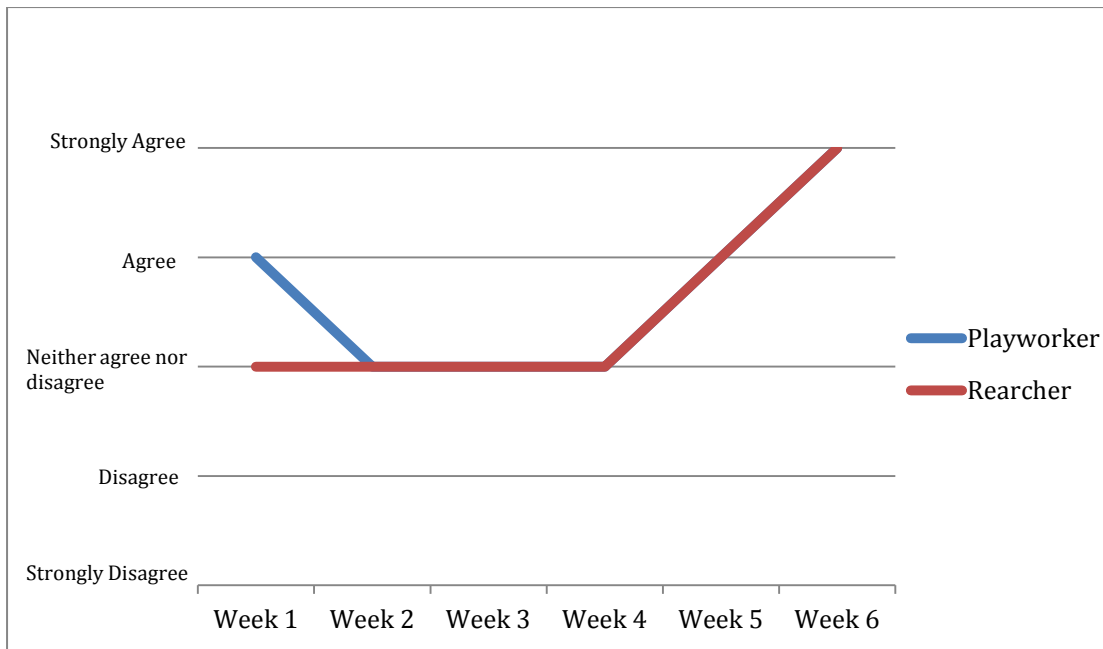


Figure 47: Perceptions of the students' ability in relating previous activity knowledge to newer tasks

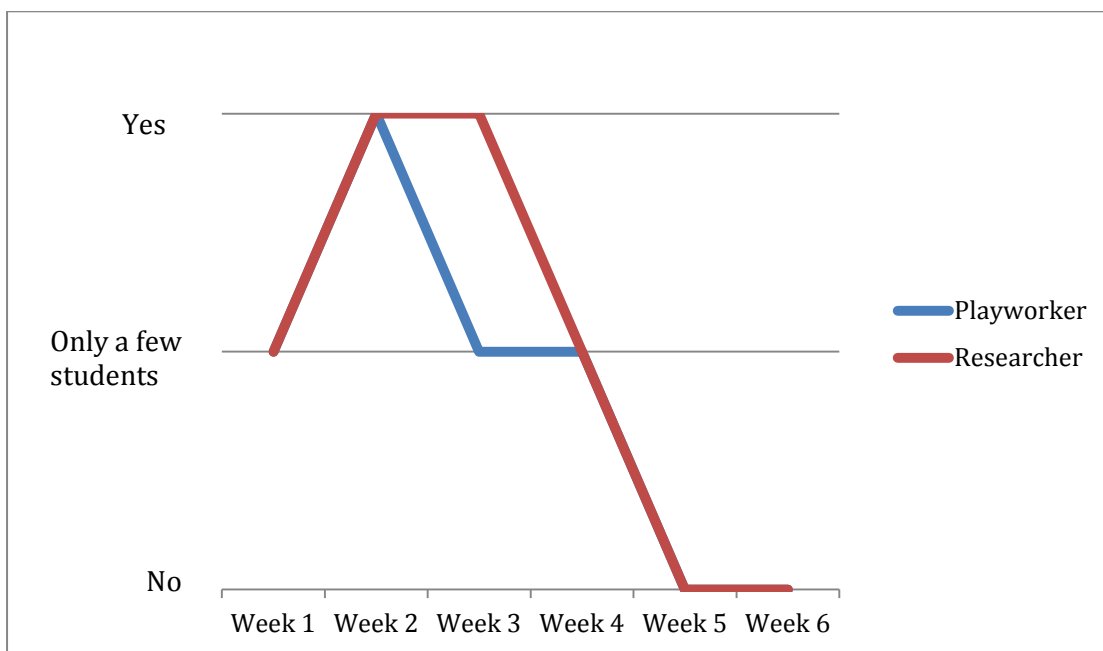


Figure 48: Perceptions of students having pre-knowledge of the presented technical vocabulary

In the first week, Figure 16 shows that only a few students understood the presented jargon. Since the students had limited knowledge of D&T prior to the research, the students related the presented jargon with their general knowledge. Students were able to learn the jargon's meanings through D&T related activity briefings and discussions. This can be observed through the following an end of week discussion, reminding students of new learnt terms:

Researcher: Do you remember what the net of a shape is?
Students: Example a cuboid, a pyramid... You would have various shapes (one student indicates a square with fingers) stuck to each other, upon which folded would create a 3D shape.

Researcher: Do all these shapes necessary have to be squares?
Students: You can have triangle, triangle, triangle, triangle and a square
(Student indicating pyramid sloping sides with hands).
Researcher: Those shapes would result in the net of a Square based Pyramid.

Students immediately understood the technical jargon presented in weeks 2-4, as shown in Figure 16. This was due to through similar D&T principles and concepts shared through the activities. Example: The word 'Bearing' was initially taught whilst engaging students in the Balloon propelled car activity (Figure 1). The word 'Bearing' was later used in other activities containing rotating systems as in Figures 3-5.

In the last two weeks, no student had any pre-knowledge of the presented jargon. This was due to the introduction of more complex jargon in 'Electricity' and 'Mechanisms' topics (Example: L.E.D., Sprocket). Upon simplifying and relating the new words' definitions to previously learnt knowledge, the students immediately understood the new words. This occurred since the students were only new to the words, yet had plenty of knowledge on the topics through previous briefings. This was shown in Figure 15, whereas students showed a remarkable ability to relate to previous knowledge throughout the last two weeks.

Figure 15 also shows that students were not showing considerable signs of relating knowledge throughout the first 4 weeks. This was due to the students still building on the D&T related knowledge necessary for defining the newly presented jargon at weeks 4-6. The progress through the last weeks shows that students started learning technical jargon via relating them to knowledge gained through previous activities. The ability relates to the students' increase in conceptual combination. This was noted through the ability to relate new bodies of knowledge with older bodies of knowledge. Conceptual combination promoted creativity in the generation of new ideas, which aided the students in the coming up with original solutions for obtaining results.

Conclusion

Throughout the six weeks, students enhanced their motor skills for manipulating tools in the correct way. This correlates with the ability to choose the right tools for the job. The pre-selection of tools evidences activity conceptualization. Students were able to imagine the finished product, and the leading stages by which the product could be achieved. The conceptualization also correlated with analogous thinking, enhancing the creative process. This was seen through students' use of new technical jargon. The acquisition of technical jargon was found to enhance the students' abilities at expressing themselves more clearly, through technical definitions and concepts. Being clearer in their way of expressing ideas thus led the students to recognize and address any issues generated whilst coming up with solutions to satisfy the activity's situation. In conclusion, the inclusion of D&T related activities in summer schools have the potential to enhance students' creative abilities. Such experiences should provide them with technological skills, complimenting intellectual and cognitive development. Such a summer school programme however involves adequate Playworker training at gaining the necessary knowledge on how to correctly convey the activities' aims.

References

- Warr, A. M. (2007, 6). Understanding and Supporting Creativity in Design. 27-48.
- Barlex, D. (2011). Achieving Creativity in the Technology Classroom: The English Experience in Secondary Schools. In M. H. Moshe Barak, *Fostering Human Development Through Engineering and Technology Education* (Vol. 6). ROTTERDAM/BOSTON/TAIPEI, The Netherlands: SENSE PUBLISHERS.
- Bruce A. Marlowe, D. A. *Educational Psychology in Context: Readings for Future Teachers* (1st Edition ed.). California: Saga Publications, Inc.
- Directorate for Quality and Standards in Education. (2015). *DESIGN AND TECHNOLOGY CURRICULUM FORM1&2*. Department of Curriculum Management Design and Technology Learning Centre, Malta.
- Directorate for Quality and Standards in Education. (2009). *National Policy and Strategy for the Attainment of Core Competences in Primary Education*. Directorate for Quality and Standards in Education. St. Venera Malta: Directorate for Quality and Standards in Education Ministry of Education, Culture, Youth and Sport, Malta.
- Djilas, M. (2008). *Interpretation of Sensory Information From Skeletal Muscle Receptors For External Control*. Retrieved 10 17, 2018 from HAL archives-ouvertes.fr: <https://tel.archives-ouvertes.fr/tel-00333530/document>
- Fox-Turnbull, W. H. (2013). *The Nature of Conversation of Primary Students in Technology Education: Implications for Teaching and Learning*. Hamilton, New Zealand: University of Waikato.
- Johnston, J. C. (2002). *Developing Teaching Skills in the Primary School*. Buckingham: Philadelphia: Open University Press.
- National Advisory Committee on Creative and Cultural Education (NACCCE). (1999). *All Our Futures: Creativity, Culture and Education*. the Secretary of State for Education and Employment, Secretary of State for Culture, Media and Sport.
- Northgate High School. (2017). *Design & Technology*. Retrieved 10 17, 2018 from Northgate High School: <https://www.northgate.norfolk.sch.uk/design-technology/>
- MATSEC. (2020). *SEC SYLLABUS (2020) DESIGN AND TECHNOLOGY*. Retrieved 3 29, 2019 from https://www.um.edu.mt/__data/assets/pdf_file/0019/317701/SEC33.pdf
- Sowa J.F., M. A. (2003). Analogical Reasoning. (d. M. Ganter B., Ed.) *Conceptual Structures for Knowledge Creation and Communication*. , 2746, 16-36.
- Stevens, P. (1972, 1). Technical, Technological and Scientific English (TTSE). *ELT Journal* .

