"learning by doing" research INTRODUCTION*

BY JOHNNY J MOYE, DTE, WILLIAM E. DUGGER, JR., DTE, and KENDALL N. STARKWEATHER, DTE

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WHAT IS "DOING"?

The United States has been known as a nation of doers. Is this still true, or are we becoming a nation of passive viewers who stay glued to the computer screen, television, or other form of diversion—rather than being active tactile learners who should be learning by doing?

The word "doing" is used in many ways in the English language. "Do" could be used as a verb giving a meaning of action, performance, and execution as "doing." Some everyday phrases we recognize are: "this was more of my doing …", "getting it finished by tomorrow will take some doing," "doing time," "any job worth doing is a job worth doing well," "let's do it, let's fall in love," "just do it," "what are you doing," and many others.

The research in this Learning by Doing study focuses on a special type of doing that applies to science, technology, engineering, and mathematics (STEM) education. This initiative will use the word doing as defined below:

> DOING: "A tactile/hands-on process of technological problem solving starting with human needs and wants that leads to the principles of innovation such as designing, making/building, producing, and evaluating."

Elementary and secondary technology and engineering teachers use this type of doing in their courses. Many science and mathematics teachers could also perform the same type of doing in their courses.

Over the past several years, science and mathematics teachers have been directed to prepare their students for taking high-stakes tests. Both teachers and students experience the pressures of "teaching to the test." This scenario makes the test the focus of the curriculum, and the learning experience is primarily based on "cognitive education." As a result, John Dewey's "learning by doing" philosophy (Dewey, 1938) has been seriously undermined in today's education system.

WHY IS LEARNING BY DOING IMPORTANT?

In the early stages of humankind, the act of doing was essential for survival and drove the evolution of technology. For example, the earliest prehistoric technology used by humans was the use of chipped stones. These chipped stones were used to kill animals, to prepare pelts for clothing, and to carve meat for food, as well as for digging and other uses. Chipped-stone technologies were later used to develop tools such as axes, arrowheads, and spears. Development of these technologies required knowledge as well as the application of that knowledge. As was true in ancient times, knowledge and the ability to use that knowledge (to do) remains essential for survival of the human race.

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WHY IS THERE A NEED FOR THIS STUDY?

There have been no studies of this topic in the past, and this may be the only study in the U.S. that compares the level of "doing" in Grades 3 through 12 STEM courses. The National Research Council reported that one of the most pressing issues facing education today is that data needs to be collected to determine to what extent "classroom coverage for content and practice [doing] in the *Common Core State Standards for Mathematics* and *A Framework for K-12 Science Education*" (NRC, 2013, p. 36) was occurring in U.S. public schools.

Engineering and technology practice is a major section within *Next Generation Science Standards* (*NGSS*, 2013), yet no research has been conducted on the amount of doing taking place as it relates to these practices. The *NGSS* engineering practices need to be researched for the amount of doing occurring within those standards. This study will help to address these concerns.

STEM education is more than just learning the four separate content areas that comprise the STEM acronym. It is about students learning to do something with knowledge (Honey, Pearson, & Schweingruber, 2014; Katehi, Pearson, & Feder, 2009; NRC, 2011). STEM education challenges students to perform practical application of the laws, principles, theories, practices, designs, and processes of each STEM area as well as understand the context in which they are applied.

STEM education is a relatively new and growing integrated curriculum effort. In the past, STEM subject areas were taught separately and in isolation (or silos) from one another, with little or no attempt at content integration (Katehi, Pearson, & Feder, 2009). It is believed that by integrating STEM content into lessons and activities, students will become more interested and motivated to learn due to their improved understanding of the real-world connection and relevance of what they are learning. The desire is, with the STEM education movement, students should not only remember facts and figures, but also understand how to do something with the information that they learn in these four subject areas (Honey, Pearson, & Schweingruber, 2014).

Mathematics and science courses are required for all public schools at most grade levels today, while technology and engineering courses are not. Historically, technology content has been taught in technology education, an elective course. School leaders may not realize that technology and engineering competencies are included in ITEEA's *Standards for Technological Literacy: Content for the Study of Technology* (*STL*) (ITEA/ITEEA, 2000/2002/2007). Therefore, for almost two decades technology and engineering programs have taught engineering content.

MORE ABOUT STEM EDUCATION AND THIS RESEARCH

With all the recent discussion surrounding STEM education, several questions continue to surface: what is it, why it is important, and how to deliver it in the classroom (Honey, Pearson, & Schweingruber, 2014)? The acronym itself is easy enough to understand—STEM (science, technology, engineering, and mathematics)—but it is the acronym's combined meaning and required method of delivery that may not be fully understood. The authors of the *Successful STEM Education: A Workshop Summary* document, stated:

> The term "STEM Education" is shorthand for an enterprise that is as complicated as it is important. What students learn about the science disciplines, technology, engineering, and mathematics during their K-12 schooling shapes their intellectual development, opportunities for future studies and work, and choices of career, as well as their capacity to make informed decisions about political and civic issues and about their own lives (NRC, 2011, p. 1).

Students still ask the age-old question, "Why do I need to know this?" That question is relevant and must be adequately answered by educators. A teacher could explain that to be successful in life, students will need to be able to "move back and forth between the acquisition of disciplinary knowledge and skill and their application to problems that call on competencies from multiple disciplines" (Honey, Pearson, & Schweingruber, 2014, p. 71). However, students may prefer a more readily understandable explanation that could be something like, "You need to know science, technology, engineering, and mathematics in order to understand how things in this world work, how everything is interconnected, and how to use that information when needed."

Technology and engineering presents doing-based activities where students can actually use STEM to find answers to issues or to solve problems. Therefore, technology and engineering is the logical subject matter area to deliver STEM education. *Standards for Technological Literacy* provides 20 content standards that address the "T" and "E" in STEM as well as how and when to use the M and S. The *Next Generation Science Standards* (*NGSS*) framework includes engineering and technology information and practice requirements (*NGSS*, 2013a). This is a significant addition to the science content. While it is positive that science education recognizes the importance of engineering and technology, the concern is how to incorporate the additional curriculum and activities in an already full science curriculum. There appears to be little, if any, time to practice the modeling, prototyping, and experiments as *NGSS* requires. Should the modeling requirement remain, science teachers will still be responsible for preparing students for standardized tests to demonstrate competency. The *NGSS* authors recognize that science teachers will likely be unprepared to bear the entire load. Fortunately technology and engineering is an asset already available in many schools.

The decision to integrate engineering design into the science disciplines is not intended either to encourage or discourage development of engineering courses. In recent years, many middle and high schools have introduced engineering courses that build students' engineering skill, engage them in experiences using a variety of technologies, and provide information on a large range of engineering careers. The engineering design standards included in *NGSS* could certainly be a component of such courses but most likely do not represent the full scope of such courses or an engineering pathway. (NGSS, 2013a, p. 107)

The above statement recognizes that engineering already exists and alludes to the fact that collaboration between the science, technology, and engineering communities is necessary. Now that *NGSS* is available for states to use, curriculum developers should recognize the benefits of creating their curriculum integrating science, technology, and engineering courses.

In the late 1990s and early 2000s, there were numerous nationally developed content standards for most K-12 subject areas. Many of these standards identify that students need to have an understanding of (the knowledge) and be able to use what they learn (the doing) to be literate in a particular subject matter. *Common Core State Standards for Mathematics* says, "Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace" (CCSSM, 2010, p.7). *Next Generation Science Standards* "are standards, or goals, that reflect what a student should know and be able to do" (*NGSS*, 2013b, p. xiv). *Standards for Technological Literacy* presents "a vision of what students should know and be able to do in order to be technologically literate" (ITEA/ITEEA, 2000/2002/2007, p. vii). It should be noted that *NGSS* and *CCSSM* use the word "practice" for the act of "doing."

These standards identify the content of what we teach U.S. public school students. Even though standardized (high-stakes) testing is a controversial issue, this practice is and will remain a fact of life for the foreseeable future. A "growing emphasis on standardized competency tests has encouraged schools to teach to those tests, which generally contain few questions gauging technological literacy" (ITEA/ITEEA, 2000/2002/2007, p. 3). Students are learning to take science and mathematics (and other) standardized tests to determine their level of knowledge (cognitive ability) rather than their ability to actually do something with that information (application ability). This approach presents a problem when students are expected to use the information for other than test-taking purposes (Martinez & Stager, 2013).

The National Assessment Governing Board (NAGB)/National Assessment of Educational Progress (NAEP) will use the 2014 Technology and Engineering Literacy (TEL) assessment to assess U.S. students' "ability to 'do' engineering or produce technology…to gauge how well students can apply their understanding of technology principles to real-life situations" (NAGB, 2013, p. 2). The NAGB/NAEP defines technology and engineering literacy as the "capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals." (NAGB, 2013, p. 3). As the definition suggests, technology and engineering literacy requires more than just knowledge, but also how to use that knowledge. The 2014 TEL will use a computer-based interactive method to assess students. With the new method of assessment comes an added challenge to improve student performance on those assessments. Considering the time and resources available, only technology and engineering courses prepare students for these TEL assessments.

Technology and engineering courses have the capability to bring true STEM education to fruition. These courses present students with opportunities to apply the information they learn in core academic courses to solve problems. In addition to using hands-on skills required to solve practical problems, technology and engineering also presents students with the view and application of laws, principles, theories, practices, designs, and processes. These characteristics are necessary to be successful in school, the workforce, and life in general (Moye, 2011).

SELECTED FINDINGS AND SUMMARY

The authors will conduct the Learning by Doing study over the next three years. The first round of surveys was conducted in March/April of 2014, with results tabulated and analyzed. Selected findings are:

- Teachers feel that students benefit from doing activities in their classrooms.
- Teachers would have their students do more activities/projects in class if they had the time and resources.

- Middle and high school technology and engineering students are learning by doing more than are students in science and mathematics classrooms.
- Middle school students are doing more activities and projects than are elementary and high school students. Elementary education students are doing more than high school students.

The researchers found that learning by doing continues to be a primary interest and value to STEM teachers of Grades 3-12. Various comments centered on teacher desire to have more time for doing activities as a part of their instruction. Standardized testing was identified as an obstacle to the completion of additional doing experiences. Learning by doing was confirmed as an essential, but underutilized, method of learning. The authors look forward to the next three years of further exploration of learning by doing.

In summary, the intent of this article is to announce the study, provide reasons why doing in classrooms is important, show how technology and engineering provides learning by doing opportunities, and provide selected findings of the first round of the study. The authors encourage STEM teachers to use technology and engineering programs to support student learning by doing and to participate in the next three rounds of this study. The next round of surveys can be accessed at this link: www.iteea.org/DoingProject.pdf. (A second article reporting the data collected will be published in the November 2014 issue of *Technology and Engineering Teacher*.)

REFERENCES

Council of State School Officers (CCSSO) and National Governors Association Center for Best Practices (NGA Center). (2010). Common core state standards initiative: Standards for mathematical practice. *Common Core State Standards for Mathematics* (*CCSS*). Washington, DC: Author.

Dewey, J. (1938). *Experience and education*. Toronto: Collier-MacMillan Canada, Ltd.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM integration in K-12 education: Status, prospects, and an agenda for research.* Washington, DC: The National Academies Press.

ITEA/ITEEA. (2000/2002/2007). *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects.* Washington, DC: The National Academies Press.

Martinez, S. L. & Stager, G. (2013). *Invent to learn: Making, tinkering, and engineering in the classroom.* Torrance, CA: Constructing Modern Knowledge Press.

Moye, J. J. (2011). The promise of technology and engineering education. In Ritz, J. M. & Bevins, S. P. (Eds.) *The Connection to the 21st Century Workforce: Technology and Engineering Education*, 22-33, Reston, VA: ITEEA.

National Assessment Governing Board (NAGB). (2013). *Technology and engineering literacy framework for the 2014 national assessment of educational progress.* Washington, DC: NAGB.

Next Generation Science Standards (NGSS). (2013a). *Next generation science standards: For states by states (Vol. 2).* Washington, DC: The National Academies Press.

Next Generation Science Standards (NGSS). (2013b). *Next generation science standards: For states by states (Vol. 1)*. Washington, DC: The National Academies Press.

National Research Council (NRC). (2013). *Monitoring progress toward successful K-12 education: A nation advancing?* Committee on the Evaluation Framework for Successful K-12 STEM Education. Board on Science Education and Board on Testing and Assessment, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Johnny J Moye, Ph.D., DTE *recently retired from his position as a Supervisor of Career and Technical Education at Chesapeake Public Schools, Chesapeake, VA. He can be reached at johnnyjmoye@gmail.com.*

William E. Dugger, Jr., Ph.D., DTE *served as Director of ITEEA's Technology for All Americans Project, which developed the landmark* Standards for Technological Literacy *and* Advancing Excellence in Technological Literacy *documents. Dugger is an Emeritus Professor at Virginia Tech and serves as Senior Fellow for ITEEA. He can be reached at wdugger@iteea.org.*

Kendall N. Starkweather, Ph.D., DTE, CAE *is former Executive Director/CEO of ITEEA. His career has focused on advancing technology and engineering education worldwide as a teacher and teacher educator. He has worked for over three decades to determine direction and set policy for technology and engineering education at the national and international levels through association politics and policy. He is a distinguished graduate of the University of Maryland, a Distinguished Technology and Engineering Educator, and member of ITEEA's Academy of Fellows.*