Promoting Excellence in Preparation and Excellence in Practice

Volume XXXV1, 2010
No. 1 Spring 2010

The Journal of Technology Studies

Locating the T in STEM

A refereed publication of Epsilon Pi Tau The International Honor Society for Professions in Technology.

The Journal of Technology Studies

A refereed publication of Epsilon Pi Tau The International Honor Society for Professions in Technology.

Jerry Streichler, Founding Editor and Publisher from 1977-2006

The Journal of Technology Studies (JTS) (ISSN 1071-6048) is the flagship, peer-reviewed journal of Epsilon Pi Tau, Inc., a nonprofit, academic and professional honor society. Headquarters and editorial offices are located at the Technology Building, Bowling Green State University, Bowling Green, OH 43403-0296. Use this address or jots@bgsu.edu for subscription matters or purchases.

Two print issues per year are mailed to all members of the society upon request and to academic and general libraries around the globe. Issues that are published online only, the aforementioned printed issues, and past issues are available online at scholar.lib.vt.edu/ejournals/JTS.

The journal is currently indexed in Current Index to Journals of Education (USA), International Bibliography of the Social Sciences (IBSS) (UK), and the International Vocational Education and Training and Research Database at http://www.ncver.edu.au (Australia).

Separate articles or complete issues are also available in a variety of media forms from National Archive Publishing Company, P.O. Box 1346, Ann Arbor, MI 48106-1346, EBSCO Publishing, 10 Estes Street, Ipswich, MA 01938-0682, USA, and ERIC, 655 15th Street NW Suite 500, Washington, DC 20005, USA.

The JTS welcomes original manuscripts from scholars worldwide focused on the depth and breadth of technology as practiced and understood past, present, and future. Epsilon Pi Tau, as perhaps the most comprehensive honor society among the technology professions, seeks to provide up-to-date and insightful information to its increasingly diverse membership as well as the broader public. Authors need not be members of the society in order to submit manuscripts for consideration. Contributions from both academics and practitioners are equally welcome.

A general guide to the breadth of topics of potential interest to our readers can be gained by consideration of the 17 subclasses within "Technology" of the classification scheme of the Library of Congress, USA <lcweb.loc.gov/catdir/cpso/lcco/lcco_t.pdf>. This includes engineering and allied disciplines, informatics in its many manifestations, industrial technology, and education in and about technology.

Authors are strongly urged to consult the journal's "Guidelines for Authors," included in this publication, or available at the society's Web site (www.eptglobal.org) or provided upon request. It provides additional details on the breadth and nature of topics of interest, the journal's scholarly writing standards, submission guidelines, and review and publication processes.

Printed in the United States of America by Kennedy Printing Company, Findlay, Ohio.

Table of Contents

Volume XXXVI, Number 1, Spring 2010

Staking the Claim for the 'T' in STEM

Todd Kelley

Introduction

There are a number of examples in technology education history of multidisciplinary and interdisciplinary efforts linking technology education with other disciplines; however, there has never been a time in technology education where multidisciplinary and interdisciplinary efforts are not only promising but also may be essential for the prosperity of technology education. One important example of blurred boundaries caused by a multidisciplinary effort from our recent past was the Math, Science, and Technology (MST) movement in the early 1990s. The MST movement had an important impact on technology education, and a strong case can be made that the MST efforts of the 1990s paved the way for the recent STEM education initiatives. However, in this article, the author will seek to make the case that no previous multidisciplinary and interdisciplinary efforts within technology education's history has such potential to impact the field greater than the recent Science, Technology, Engineering, and Mathematics (STEM) movement. Here, the terms *multidisciplinary* and *interdisciplinary* will be defined, a recent history of such efforts in technology education will be reviewed, how funding can and has blurred the mission of technology education will be explored, and the opportunities for technology education regarding STEM education will be presented.

Multidisciplinary and Interdisciplinary defined:

The terms multidisciplinary and interdisciplinary have become educational "buzzwords," and these terms have been misused, abused, and often used interchangeably, thus, adding to the confusion of how these terms are used in practice.

Multidisciplinary has been defined as "individuals from different disciplines working independently on different aspects of a project" (Mallon & Burton, 2005, p. 2).

Interdisciplinary understanding has been defined as "the capacity to integrate knowledge and modes of thinking drawn from two or more disciplines to produce a cognitive advancement—for example, explaining a phenomenon, solving a problem, creating a product, or raising a new question—in ways that would have been unlikely through single disciplinary means" (Mansilla, 2005, p.16).

The MST Movement

The United States Industrialist Henry Kaiser once said, "Trouble is only opportunity in work clothes" (Phillips, 1993, p. 8). The MST movement began as a result of trouble within U.S. schools, specifically the need to improve American students' scores in math and science. National reports such as *Everybody Counts: A Report to the Nation on the Future of Mathematics Education* (National Research Council, 1989) and *Project 2061: Science for All Americans* (American Association for Advancement of Science, 1989) documented the need to improve students' knowledge and understanding of math and science. Likely some members within technology education believed the MST movement was an excellent opportunity for technology education to position itself as a necessary discipline for all learners and provide a necessary funding source for technology education. Householder (1992) indicated that technology teacher education had an excellent opportunity in the MST movement to locate funding for undergraduate education that was once only possible for science and mathematics education; whereas other technology education leaders indicated that MST would elevate the status of the field (LaPorte & Sanders, 1993). Equally, technology education leaders questioned technology education's chances of survival with two core disciplines (Foster, 1994; Gloeckner, 1991). Gloeckner (1991) provided examples of possible roadblocks that would limit the success of the MST movement for technology education. Moreover, Daugherty and Wicklein (1993) conducted research to determine the perceptions held by math, science, and technology teachers' of technology education. The results revealed that they were poor and that misconceptions abound regarding technology education.

One project that emerged out of the MST movement was the New York State Technology Education Network (NYSTEN), which was funded by the NSF to improve the quality of technology education in that State. The NYSTEN project was designed to provide contemporary technological, pedagogical, and leadership enhancement to technology education teachers across New York state (Burghardt & Hacker, 2002). This author was a member of the NYSTEN project as a secondary technology teacher during the 1994-1996 school years. Through the experiences of piloting a MST middle school project and assisting in the writing of a middle school MST project assessment instrument, author witnessed the removal of barriers among math, science, and technology education teachers. Furthermore, a new social network of educators was formed as in-service teachers from math, science, and technology education disciplines gathered for summer professional development workshops and to draft MST curriculum and MST standards for New York State (Liao, 1998). However, once federal funds ran out, such as Goals 2000 monies, the MST movement lost critical momentum and the MST standards project for New York State has never been fully implemented as designed. Certainly, other factors were at work regarding the New York State MST movement beyond a funding issue. The New York State Department website states:

> Through the foresight of many, the standard for technology and technology education programs was linked to mathematics and science. Illustrating the interconnectedness of these three subjects the Mathematics, Science, Technology (MST) Learning Standards has created a dynamic force for demonstrating student knowledge. While mathematics and science have had a long history in education, technology education is a relatively new subject with less stature and acceptance. Added to this the testing pressures placed on mathematics and science education, technology education has been overlooked as a tool for improving student achievement (NYS Technology Education Framework Initiative, 2006, p. 4).

This statement supports the positions of Gloeckner (1991), Foster (1994), and others who warned of the dangers of technology education becoming the stepchild in a bad marriage of math and science. Technology educators must learn from these past events in order to provide a vital case for technology education in the STEM movement.

The Blurs of Funding

There are countless examples of educational funding providing a "blurring of the boundaries" effect within the field of technology education. In fact, researchers can go all the way back to the days of Woodward and the manual training movement to see a prime example of "border crossing." Often, those who view technology education as a part of general education are sometimes forced to consider a compromise when faced with the idea of missing out on federal funding that supports career and technical education. Lewis (1996) uses Woodward as an example of one who was forced to compromise his ideals for manual arts for all children's general education. Woodward possessed a liberal education viewpoint of manual training that moved way beyond manual training as trade training; however, with the passing of the Smith-Hughes Act of 1917, Woodward was faced with a "border crossing." Supporters of manual training viewed it as a way to loosen a union stranglehold on apprenticeship; consequently, Woodward and his "camp" were forced to advertise manual training as vocational training and not a liberal education for all in order try to gain Smith-Hughes monies. This "fence sitting approach" has been a sore spot in the field of technology education for some time (Karnes, 1999). Although this "blurring of borders" is related to the mission or purpose of technology education, it does serve as an example of the dangers of following the funding and the affect that it has on a discipline. This could be a root cause for why some educators have indicated that technology education has failed to establish its mission (Wicklein, 2006).

It is with careful consideration of our past regarding "border crossing" that technology education leaders should count the cost of seeking federal STEM dollars. Currently, 85 NSF programs include STEM somewhere in the RFP solicitation (NSF Website, date accessed 8/29/09). The current $787 billion stimulus package contained $100 million for the National Science Foundation (Riley, 2009). Sanders (2009) pointed out that during the past 20 years there has been major education reform through major professional associations and crediting boards regarding science, mathematics, technology, and engineering disciplines (e.g., AAAS, 1989, 1993; Peterson, 1996; ITEA, 1996, 2000; NCTM 1989, 2000; NRC, 1994), illustrating the massive efforts to improve STEM education.

Unquestionably, a great opportunity exists for those in technology education to conduct research in STEM education. However, there are other opportunities for technology educators to capitalize on STEM initiatives beyond simply research efforts. The National Science Board identified the critical need for STEM teachers within the next decade. “In the next decade, the Nation is going to need “2.2 million new teachers in K-12 schools and community education settings. The greatest need now and into the future is for teachers in the STEM areas” (National Science Board, 2007, p. 1). Undoubtedly, technology teacher educators have an excellent opportunity to focus on the preparation of pre-service STEM teachers. It may be appropriate for technology educators to consider revamping technology teacher education programs to ensure that technology teacher education takes ownership of the T in STEM.

Blurring of the T in STEM

Certainly, a blurring of the boundaries within the STEM acronym includes an interpretation of the T in STEM. How is technology defined by those proposing a STEM approach to education? Most if not all technology educators would suggest that technology education is the T in STEM. However, outside our field do other educators, educational policymakers, school officials, and the holders of educational funding recognize that we deliver the T in STEM? Does the general public know what the T in STEM is? It is well documented that technology educators have struggled to define the discipline (Wicklein, 2006)? Technology educators have struggled with the field’s purpose or mission, which may have been a result of “border crossing” (Lewis, 1996). There has even been a struggle with the name “technology education” (Clark, 1989). These factors have caused some to suggest that technology education struggles with its identity. To illustrate this point, when someone asks what a technology educator does for a living, much of that conversation is about what the person is “not.” They also note that technology education should not be confused with educational technology and that many technology educators are former Industrial Arts or shop teachers, but they are not that anymore. It is no secret that technology educators, struggle to define who they are. Furthermore, it is important to recognize that they currently <u>do not</u> own the T in STEM from the general public’s perception. *Education Week* (March, 27th, 2008) published an entire issue centered on STEM education where throughout the publication were success stories of STEM education around the nation. If one reads the articles in depth, most of the examples of the T in STEM education are representative of informational technology or educational technology more than they reflect technology education practice. Moreover, when the national scorecard reports on STEM are examined, the T (technology) is measured by counting the number of computers schools had accessible for student use. One article in the *Education Week* STEM issue was titled, “Where Is the T in STEM?” (Cavanagh, 2008). In this article, experts debated if the practical application of math and science was getting the national attention it deserved. These examples continue to cause members of technology education to wonder if the field will ever be recognized as the T in STEM and it furthers the misconceptions of technology education and fosters dissention among STEM disciplines. Now is the time to raise the all-important question: How can technology educators stake their claim on the T in STEM?

Staking the Claim for the T in STEM

A key for defining the T in STEM is *research*. In order for the field of technology education to be known as the T in STEM separate from the science, math, and engineering community, it must rely on quality, relevant research. Quality research results speak to educational leaders and policymakers in a way that is meaningful and powerful. Technology education has countless publications that are little more than PR pieces of success stories related to effective outcomes indicating that students become motivated to learn because of technology education classes. Although there are many examples of the power of project- and design-based instruction, this does not mean much to educators outside the field of technology education until research confirms it. It is not enough to say that students are engaged and excited about learning because of technology education programs. It is not enough to say that kids are finally connecting their science and math skills because of technology education. Technology education doesn’t need more public relations pieces regarding its value; it needs more research studies to get at the core of how technology education improves learning. It is well documented that this field lacks quality rigorous research. From Sanders in 1987 to more recent reports from Foster (1992), Petrina (1989), Zuga, (2000) and Lewis (1999), all documented a great need for more research in the field of technology education. Interestingly, Gloeckner (1991) accurately indicated that one of the major roadblocks at that time for technology education's success with the MST movement was the lack of funding for educational research. Today, there has never been a better time to conduct research on interdisciplinary education efforts because of the STEM movement. This movement is not simply another example of the latest pedagogical strategy to improve American students' scores in math and science; some experts suggest that STEM education has major national, economic, and security implications. Chairman of the National Science Board sent a one-page letter on 11 January 2009, to President-Elect Obama as a call to action regarding the improvement of STEM education for all students. In this letter, Chairman Beering stated:

> Our national economic prosperity and security requires that we remain a world leader in science and technology. Pre-college STEM education is the foundation of that leadership and must be one of our highest priorities as a Nation. We urge the new Administration to seize the opportunity provided by this special moment in history and mobilize the Nation to support the development of high quality STEM knowledge and skills for all American students. It is essential that we act now to ensure all of our children and American society as a whole can continue to prosper in the 21st century technology-based economy (National Science Board, 2009).

The letter also identified core components of an effective STEM educational system, including promoting student learning in STEM that encourages critical- thinking, communication, and problem solving-skills, increases to teacher salaries to recruit and retain high-quality STEM teachers, provides advanced technologies for the classroom, and provides federal funding for peer-reviewed and competitively funded research on the learning and teaching of STEM education.

K-12 Design-based Instruction Research (Outside Technology Education)

Technology educators should learn from researchers outside of the field whom are researching education constructs that align with technology education's traditional pedagogical approaches, including project-based instruction, design-based instruction, and service-learning approaches to design and problem solving. For example, recently project-based learning has been successfully implemented in science classrooms to improve science instruction and develop skills of scientific inquiry (Krajcik & Blumenfeld, 2006). Although project-based learning (PBL) is not exclusively a design-based approach, the learning theories align, and many project-based learning experiences contain an embedded design approach. Research confirms that project-based learning has been successful at increasing students' tests scores compared to student test scores in traditional classrooms (Marxet al., 2004). Furthermore, research on project-based science instruction revealed that this instructional approach could help all students regardless of culture, race, or gender (Atwater, 1994; Geier, et al., 2008; Haberman, 1991).

Researchers at Tufts University and Boston College (Rogers, Jarvis, & Barnett, n.d.) have developed engineering-based science units for grades 3 and 4 using LEGO™ kits. The projects' focus was to infuse engineering concepts into elementary education while improving the teaching and learning of science. Case-based reasoning is another approach to design-based instruction. Kolodner (2006) developed an approach to design-based instruction based on a case-based reasoning theory. Kolodner named this middle school level educational approach to project-based inquiry *Learning by Design*. The *Learning by Design* approach engages students into two essential cycles: design/redesign and investigate/explore. Students experience a variety of doing and reflecting activities and share their new knowledge in public presentations as a way to help students process these experiences and make connections with core content knowledge (Kolodner, 2006). Technology educators would be best served by learning from educational researchers outside technology education whose examining constructs align well with their own pedagogical approaches. Some examples of educational research have come from technology educators who have found ways to acquire funding that aligns with STEM initiatives. For instance, Burghardt and Hacker (2003) acquired funding from an NSF's Math Science Partnership (MSP) grant to develop a contemporary pedagogical approach to design-based instruction developed for middle school technology education. Hacker and Burghardt's *informed* *design* approach allows the designer to move beyond trial-and-error problem solving that often leaves students with a lack of understanding about why the design solutions succeeded or failed. Burghardt and Hacker (2004) indicated that the informed design approach emphasizes the use of design challenges that require the application of math and science concepts through an engineering design approach in order to develop design solutions. Burghardt and Hacker's project serves as an example of an interdisciplinary (STEM) approach to engineering design-based instruction that illustrates the benefit of the "blurring of the interdisciplinary boundaries."

Making the Connection: Engineering Design and Science Inquiry

These recent science educational research findings have indicated effectiveness of using an engineering design-based approach to enhance the teaching of science inquiry (Kolodner, 2006, Krajcik & Blumenfeld, 2006). One problem remains regarding locating a logical theoretical approach to STEM education that will leverage technology education's long history with design-based instruction while at the same time retaining the core purpose: promoting technological literacy. Sanders (2009) proposed a pedagogy called "Purposeful design and inquiry" that combines technological design with science inquiry situated in the context of technological problem solving. It is clear that Sanders identifies the connection between science inquiry and design; however, the current technological design process models do not specifically engage in science inquiry or mathematical analysis (Hailey, Erekson, Becker, & Thompson, 2005). Sanders also indicated that technology education teachers like to boast about teaching science and mathematics but often fail to do so in practice. This is quite possible because they are using a design process that does not demand engagement with math and science; thus, design practice in technology education reverts to a trial-and-error method. Lewis (2006) identified the conceptual parallels of design and inquiry which provides an ideal "border crossing" for technology education and science education. Lewis identified the convergences and divergences of design and inquiry, and although much of Lewis's examples of design are centered around the engineering design process and engineering design practice (Koen, 1985; Petroski, 1994) Lewis never uses the term *engineering design* when he writes about design in this article. This author proposes that the infusion of engineering design as a logical approach to STEM education can allow technology educators to remain true to core principles and advance the STEM education cause. Engineering design provides students with a systematic approach to solving problems that not only can be used in science and engineering applications but also in many other interdisciplinary learning experiences. A graphic created with a simple combination of gears provides an illustration of this concept (see Figure 1). Using situated learning as the driver (driving gear) to engage in the engineering design process and science inquiry simultaneously is one approach to illustrate the natural engagement between the engineering design process and science inquiry. Technology education can build upon recent research results of project-based instruction, case-based instruction (Kolodner, 2006; Krajcik & Blumenfeld, 2006) and other engineering design pedagogical approaches (Burghardt & Hacker, 2004) to blend the best of these approaches to the context of engineering design. Project-based instruction research reveals that students' motivation for learning increases when allowing students to build physical artifacts, a pedagogical approach that technology educators have used successfully for years. Infusing an engineering design approach to science instruction through inquiry not only will enhance the students' ability to apply science knowledge and scientific discoveries but will also help them to apply their mathematics knowledge to inform the design process. The analytical element of the design process allows students to use mathematics and science inquiry to create and conduct experiments that will inform the designers about the function and performance of potential design solutions before a final prototype is constructed. This approach to engineering design learning will consist of authentic design tasks that allow students to build upon their own experiences and provide opportunities to construct their own new science and math knowledge through design analysis and scientific investigation. Consider situation learning as a driving gear that engages science inquiry and the engineering design process simultaneously through an authentic engineering design challenge. An authentic approach to engineering design will use science inquiry and mathematical analysis to inform the designer as he or she works through the engineering design process.

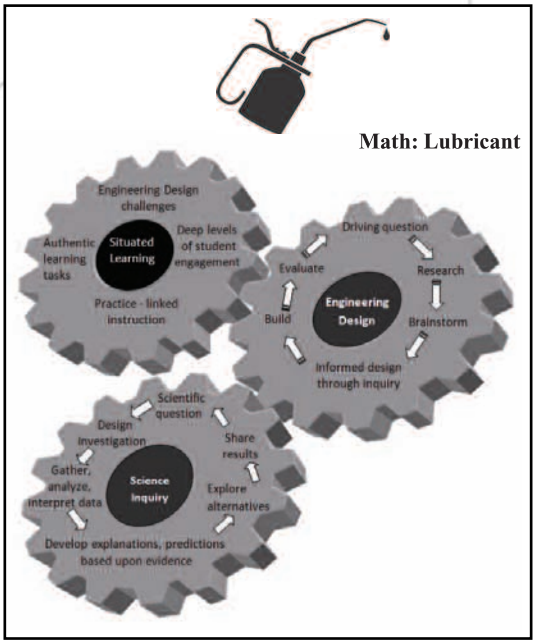

Figure 1. Relationship between Situated Learning, Engineering Design, and Science Inquiry. Assumptions: engineering design process inspired by Eide et al. (2001) revised to provide elementary age appropriate terms. The iterative process of engineering design is assumed but is not captured in this graphic.

Science inquiry may be a new term to some in technology education; however Lewis (2006) provides detailed description of science inquiry and the conceptual parallels to design creating a natural link between K-12 science and technology education. One example of a curriculum project that links science inquiry and design within technology education is an NSF-funded and ITEA-implemented curriculum project for the elementary grades (grade 5-6) is the I3 Invention-Innovation-Inquiry project. The I3 curriculum is designed to promote technological literacy through 10 units, which are standards-based learning activities engaging students in brainstorming, visualizing, testing, refining, and assessing technological designs. One unit specifically used science inquiry as a part of the design and problem-solving process (International Technology Education Association, n.d.). Clearly these curriculum developers are acknowledging the interrelationship between science inquiry and the engineering design process. Examples such as this one illustrate an approach to subject integration that captures the true essence of STEM education.

Promising Ventures in STEM education

Program revisions. There are many opportunities for technology teacher education programs to engage in STEM education. Some institutions have already altered their technology education teacher degree programs to address multidisciplinary and interdisciplinary needs, and others have approached these needs by providing opportunities for interdisciplinary endorsements for nonmajors (Virginia Tech, College of New Jersey). It is extremely important that technology teacher educators remain progressive in their approach to prepare pre-service teachers for the current conditions of secondary technology education. With more and more emphasis on STEM initiatives and movements to include engineering design as a logical vehicle for technology education to deliver STEM learning experiences, it is an appropriate time for accreditation boards such as NCATE to revisit their standards. These have been heavily influenced by a curriculum theory and conceptual framework that is nearly 30 years old (Snyder & Hales, 1981). Numerous research studies involving in-service and pre-service professional development opportunities can be used to prepare future K-12 STEM teachers; simultaneously research could be conducted to determine the appropriate levels of content and pedagogical content knowledge necessary to effectively team STEM (Brophy, Klein, Portsmore, & Rogers, 2008). Results from these studies along with research studies specific to the technology education field can provide vital information necessary to reform programs.

Informal education partnerships. One interdisciplinary venture that is very promising for technology that aligns naturally with STEM education is collaboration with Science/Technology museums. A number of educational research efforts have linked Science/Technology museums with university research efforts. This collaborative effort is a potential win-win for both institutions. One excellent museum/university approach is to field test design-based curriculum projects. Furthermore, there are many opportunities for informal educational research conducted at museums that reduces Internal Review Board (IRB) restrictions often encountered when a university is partnered with a K-12 school district. One example of informal education research partnership is the *Engineering Our Future New Jersey* a pilot project that partnered Stevens Institute of Technology with the Boston Museum of Science. Stevens Institute of Technology provided professional development opportunities for a dozen elementary teachers to help them prepare to implement the Boston Museum of Science's *Engineering is Elementary* (EiE) curriculum. The project sought to identify the impact of a pre-engineering curriculum on a student's understanding of technology and engineering concepts. Shields (2006) research on EiE curriculum materials has revealed strong gains in pre-post test scores and assessment within math and science have occurred in Colorado, Florida, Minnesota, Massachusetts, and New Jersey.

Community college, regional institutions, and research-focused partnerships.

The NSF's Advanced Technological Education (ATE) solicitation seeks research proposals with an emphasis on two-year colleges with a focus on education of technicians for high-technology fields that drive our nation's economy (National Science Foundation, n.d.). Opportunities like this RFP illustrate the shift in paradigm regarding research-focused universities. It appears that the NSF along with much of the post-secondary education community at large are moving away from a mindset that community colleges, regional institutions, and teachers' colleges are focused only on teaching to a new frame of mind that embraces research at all levels. One university with a long history as a teachers' college recently hired a president who quickly established a strategic plan to establish a strong research agenda to acquire external funding. The days of leaving research for only the land grant R-1 research institutions is a thing of the past. Research funding opportunities, such as the NSF's ATE program, provide an opportunity for colleges and universities at all levels to establish an interdisciplinary approach to STEM education in a way that leverages each institution's strengths.

No child left behind: School improvement plans through interdisciplinary efforts. In-service technology teachers have an excellent opportunity through the annual "school improvement plan" process required by NCLB legislation to improve students' standardized test scores, and regardless of how the NCLB legislation continues to be reformed and renamed, school accountability through government legislation is here to stay. All teachers are required to join a school improvement team charged to create documentation of how schools plan to improve learning in standardized-tested disciplines. School improvement teams provide technology education teachers opportunities to establish partnerships with science and mathematics teachers in order to establish plans to infuse science and mathematics concepts into existing technology education curriculum. Technology education provides a logical context for teaching math and science concepts, and often these concepts are already embedded in the technology curriculum or design activities. The school improvement report provides opportunity to document these subject integration efforts. Furthermore, establishing a partnership with math, science, and technology education teachers on these school improvement teams also provides the technology teacher with the opportunity to create powerful allies. The partnerships established through school improvement plans can generate healthy dialogues that in turn can shatter misconceptions and create positive perceptions about technology education (Daugherty & Wicklein, 1993).

Conclusion

The goal of this article was to present a strong case that no previous multidisciplinary and interdisciplinary efforts in technology education's history has such potential to impact the field greater than the recent Science, Technology, Engineering, and Mathematics (STEM) movement. A review of literature within technology education during the MST movement revealed a variety of perspectives regarding multidisciplinary and interdisciplinary efforts for technology education. Furthermore, opponents of MST for technology education identified potential pitfalls and dangers of partnering with math and science disciplines, and much of this can be revisited as possible concerns to consider within the current STEM movement. A case was made for technology education to *stake the claim* for the T in STEM by building a strong research agenda focused on STEM issues. Finally, promising ventures for technology education within STEM education were identified, including research funding sources, such as the NSF's Advanced Technological Education (ATE) to partner with two-year technical colleges, partnerships with local science and technology museums, and partnerships within schools' NCLB school improvement interdisciplinary groups. The final question unanswered remains: Who should lead these interdisciplinary efforts within technology education? The author purposefully featured a variety of STEM opportunities for technology education that include all levels of the technology education community. In order to stake the claim in the T in STEM, all members of technology education need to engage in these interdisciplinary opportunities. No one knows if STEM will rejuvenate the field of technology education, but if the members of this field are interested in becoming key players in STEM education, technology education educators must stake their claim now!

Dr. Todd Kelley is an Assistant Professor in the College of Technology at Purdue University, Indiana. He is a member of Phi chapter of Epsilon Pi Tau.

References

ABET Engineering Accreditation Commission. (2004). *ABET criteria for accrediting engineering programs.* Baltimore, MD: Author.

American Association for Advancement of Science. [AAAS]. (1993). *Benchmarks for science literacy, Project 2061*. Washington, DC: Author.

American Association for Advancement of Science. (1989). [AAAS]. *Project 2061: Science for all Americans.* Washington, DC: Author.

Atwater, M. (1994). Research on cultural diversity in the classroom. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 558-576). New York: Macmillan.

Brophy, S., Kelin, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education,* 369-382.

Burghardt, D. & Hacker, M. (2002). Large-scale teacher enhancement projects focusing on technology education. *Journal of Industrial Technology Education, 39*(3), 88-103.

Burghardt, M. D., & Hacker, M. (2004). Informed design: A contemporary approach to design pedagogy as the core process in technology. *The Technology Teacher*, 64, 6-8.

Burghardt, M. D., & Hacker, M. (2003). *The New York State Curriculum for Advanced Technological Education.* www.nyscate.net.

Cavanagh, S. (2008). Where is the 'T' in STEM? *Education Week 27*(30), 17-19.

Clark, S. C. (1989). The industrial arts paradigm: Adjustment, replacement, or extinction? *Journal of Technology Education, 1*(1), 1 -9.Daugherty, M., & Wicklein, R. (1993). Mathematics, science, and technology teachers' perceptions of technology education. *Journal of Technology Education, 4*(2), 28-43.

Education Week, (2008, March 27). STEM, the push to improve Science, Technology, Engineering, and Mathematics, *Education Week, 27*(30). From http://www.edweek.org/ew/toc/2008/03/27/index.html

Eide, A.R., Jenison, RD., Marshaw, L.H., & Northrup, L. (2001). *Engineering fundamentals and problem solving* (4th ed.) Boston: McGraw-Hill.

Foster, P. (1994). Must we MST? *Journal of Technology Education, 6*(1), 76-84

Foster, W. T. (1992). Topics and methods of recent graduate student research in industrial education and related fields. *Journal of Industrial Teacher Education, 30*(1), 59-72.

Geir, R., Blumenfeld, P., Marx, R., Krajcik, J., Fishman, B., & Soloway, E. (2008). Standardized test outcomes of urban students participating in standards and project based science curricula. *Journal of Research in Science Teaching, 45*(8), 922-939.

Gloeckner, G. (1991). The integration of science, technology, and mathematics myth or dream? *Journal of Technology Education, 2*(2).

International Technology Education Association. [ITEA]. (1996). *Technology for all Americans: A rationale and structure for the study of technology.* Reston, VA: Author.

International Technology Education Association. [ITEA]. (2000/2002) *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author.

International Technology Education Association. [ITEA]. (n.d.). *I^3 Project: Inquiry, innovation, inquiry units for technological literacy, grades 5-6.* from http://www.iteaconnect.org/i3/index.htm

Hailey, C. E., Erickson, T., Becker, K., & Thomas, T. (2005). National center for engineering and technology education. *The Technology Teacher, 64*(5), 23-26.

Householder, D. (1992). Redesign of technology teacher education: Model programs for the future. In *Camelback Symposium: Critical issues in technology education.* Reston. VA: International Technology Education Association.

Haberman, M. (1991). The pedagogy of poverty versus good teaching. *Phi Delta Kappan, 73*(4), 290-294.

Karnes, M. R. (1999). Technology education in prospect: perceptions, changes, and the survival of the profession. *Journal of Technology Studies, 15*(1), 12-35.

Koen, B. V. (1985). *Definition of the engineering method.* Washington, DC: American Society for Engineering.

Kolodner, J. L. (2006). Case-based Reasoning. In K. L. Sawyer (Ed.), *The Cambridge handbook of learning sciences* (pp. 225-242). Cambridge: Cambridge University Press.

Krajcik, J. S., & Blumenfeld, P.C. (2006). Project-based learning. In K. L. Sawyer (Ed.), *The Cambridge handbook of learning sciences* (pp. 317-333). Cambridge: Cambridge University Press.

LaPorte, J., & Sanders, M. (1993) Integrating technology, science, and mathematics in the middle school. *The Technology Teacher, 52*(6), 17-21.

Lewis, T. (1996). Accommodating border crossings. *Journal of Industrial Teacher Education, 33*(2), 7-28.

Lewis, T. (1999). Research in technology education—Some areas of need. *Journal of Technology Education, 10*(2), 41-56.

Lewis, T. (2006). Design and inquiry: Bases for an accommodation between science and technology education in the curriculum? *Journal of Research in Science Teaching, 43*(3), 255-281.

Liao, T. (1998, Summer-Fall). Ideas, technology literacy: moving beyond mathematics, science, and technology (MST) integration. *Journal of Technological Studies,* 52-64.

Mallon, W. T., & Burnton, S. (2005, June). The functions of centers and institutes in academic biomedical research. *Analysis in Brief 5*(1), 1-2.

Mansilla, V. B. (2005). Assessing student work at disciplinary crossroads. *Change, 37*(1) 14-21.

McKay, M., Macalalag, A., Shields, C., Brockway, D., & McGrath, B. (2008). *Partnership to improve student achievement through real world learning in engineering, science, mathematics and technology.* American Society for Engineering Education.

Marx, R. W., Blumenfeld, P. C., Krajcik, J.S., Fishman, B., Soloway, E., Geier, R. & Revital, T.T. (2004). Inquiry-based science in the middle grades: Assessment of learning in urban systemic reform. *Journal of Research in Science Teaching, 41*(10), 1063-1080.

National Council of Teachers of Mathematics. [NCTM]. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. [NCTM]. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Research Council. [NCR]. (1994). *National science education standards*. Washington, DC: National Academy Press.

National Research Council [NRC]. (1989). *Everybody counts: A report to the nation on the future of mathematics education.* Washington, DC: National Academy Press.

National Science Foundation, Advanced Technological Education program. Retrieved on from http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5464National Science Board, Minutes from the 396TH MEETING NATIONAL SCIENCE BOARD, March 2007. Retrieved from http://www.nsf.gov/nsb/meetings/2007/0208/minutes.pdf

New York State Education Department. (2006). NYS Technology Education Framework Initiative, pp 4. from http://www.emsc.nysed.gov/cte/technology/initiative/home.html

New York State Education Department. (1996). *Learning standards for mathematics, science, and technology.* Albany, NY: Author.

Peterson, G.D. (1996). Engineering criterion 2000: The ABET vision for change. *JOM, 48*(9), 12-14.

Petrina, S. (1998). The politics of research in technology education: A critical content and discourse analysis of the Journal of Technology Education, Volumes 1-8. *Journal of Technology Education, 10*(1), 27-57.

Petrina, S. (1993). Diversity, not uniformity; United, not standardized: A reaction to Wright's "Challenge to all technology educators." *Journal of Technology Education, 4*(2), 71-79.

Petroski, H. (1994). Design paradigms: Case histories of error and judgment in engineering. Cambridge, England: Cambridge University Press.

Phillips, B. (1993). *Phillip's book of great thoughts and funny sayings.* Carol Stream, IL: Tyndale House.

Riley, S. (2009, March 10). Tech education will get some funding from stimulus effort. I*nvestor's Business Daily Inc.*

Rogers, C., Jarvin, L., & Barnett, G. (n.d.). Transforming elementary science through LEGO™ engineering design.

Sanders, M. (2009) STEM, STEM education, STEMmania. *The Technology Teacher, 68*(4). 20-26.

Sanders, M. (1997). On research. *Journal of Industrial Teacher Education, 24*(4), 57-59.

Shields, C. (2006). Engineering our future New Jersey. *Proceedings of the 2006 Mid-Atlantic Section Conference of the American Society for Engineering Education*, Toms River, New Jersey.

Snyder, J. F., & Hales, J. A. (Eds.). (1981). *Jackson's Mill industrial arts curriculum theory*. Reston, VA: International Technology Education Association.

Wicklein, R. C. (2006). Five good reason for engineering design as the focus for technology education. *The Technology Teacher, 65(*7), 25-29.

Zuga, K. F. (2000). *Some thoughts on technology education research.* Presented at the American Association for the Advancement of Science, Conference on Research in Technology Education, Washington, DC.

Using Motorsports Design Concepts to Further STEM Education

Pete Hylton

Abstract

Few career paths are as dynamic, exciting, and engaging to potential Science, Technology, Engineering and Math (STEM) students as those in motorsports. Secondary school students, looking forward to their initial driver's licenses and their first cars, are captivated by the speed and color of the sport. Indiana University Purdue University Indianapolis (IUPUI), which offers the first Bachelor's Degree in Motorsports Engineering in the United States, has found motorsports to be an excellent mechanism for attracting STEM students, of both genders, regardless of demographic background. This article will discuss how this connection has been used to promote STEM growth.

Introduction

IUPUI has developed a program involving both Motorsports Engineering (Hylton, 2008) and Motorsports Engineering Technology (Hylton, 2007). With the rapid growth of academic motorsports programs, and the demonstrated interest by secondary school students who are investigating potential collegiate programs, it became clear that use of the technologies involved in motorsports was an excellent mechanism for engaging these students in STEM education.

Concepts related to driving a race car or working on one were initially developed as components of broader pre-engineering curriculum modules associated with a summer camp (Campbell & Hylton, 2005) for students from low socioeconomic status and minority households. The concept of the friction circle, as shown in Figure 1, was introduced as a means of determining the limits of a car's ability to travel around a corner at speed. The circle represents the limit of traction force that a race tire can supply. The tire's capabilities can be used to supply forward acceleration, braking deceleration, lateral acceleration during cornering, or a combination of these. However, there is a limit to the traction force available from the tire, which results from its friction coefficient and the portion of the vehicle load that it is carrying. This limit is represented by the circumference of the circle. The vector combination of the forces on the tire cannot exceed the overall limit of the tire's capabilities. Thus when the fore-aft (acceleration or deceleration) and lateral (sideways) force vectors are combined, the resultant must stay within the circle. Covertly, the objective of introducing the friction circle into the classroom module was to demonstrate the concept of vector math and to instruct students on how to use it. By using the theme of motorsports as a conveyance of STEM topics, the material was readily accepted by the students and they rose to the challenge.

Motorsports Concepts In Curriculum

In another example, students were challenged to develop an understanding of forces, couples, and moment arms. A torque wrench, like that used by the mechanics on a racecar, was utilized. This gave the students an opportunity to see how work was completed on the university's racecar. In addition, it provided the opportunity for students to see how the angle of application of a force, and the resulting moment arm, affect the amount of torque created by a given force application. The ability to use a mechanical advantage to lift a car via a purely mechanical jack used by many race teams was also incorporated into these classroom modules. Also, for female students who had difficulty realizing that sometimes male students are physically stronger, this showed that (with help) even the smallest

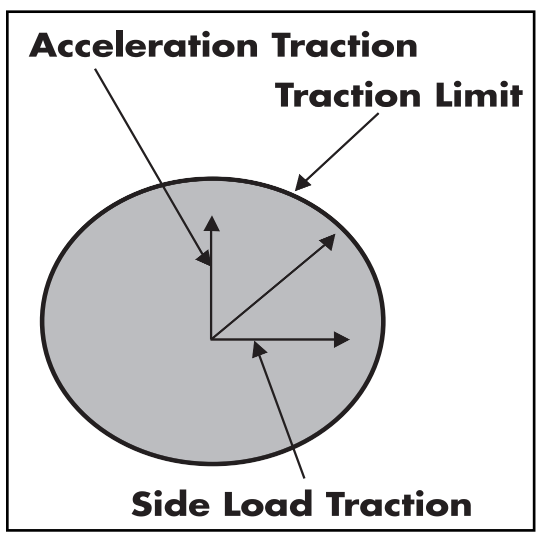

Figure 1. A friction circle is used to demonstrate how vector math relates to motorsports.

female student in the class could lift an object that was too heavy for the strongest male student. This was used as a positive reinforcing reinforcement activity (Hylton, 2006).

The lesson plans of the summer camp, which included concepts mentioned in the previous paragraph was extremely successful (Otoupal & Hylton, 2007). The camp also demonstrated that these topics are not attractive exclusively to Caucasian males. In fact, a high percentage of female and minority students were also interested by these modules (Otoupal & Hylton, 2006). This led to the development of a longer curriculum module, which could be extended from a few days to several weeks, which was aimed at both involving students in a motorsports related design project that could be tied to additional concepts from science and mathematics.

Motorsports Safety Structure Design

During the last decade, safety has been the area of greatest advancement in motorsports; partly it was the result of the loss of two of the sport's best-known drivers: seven-time National Association for Stock Car Auto Racing (NASCAR) champion, Dale Earnhardt Sr. and three-time Formula One World Champion, Ayrton Senna. As racecars have become faster, they also carry more and more kinetic energy that must be dissipated when a crash occurs. Extensive effort has been expended into designing and developing systems to absorb or distribute the energy that occurs during a crash in order to protect the driver. Some of these concepts also have been adapted to increase the safety of the average driver on the street.

Areas of safety that have seen extensive development include driver's personal safety equipment, (e.g., a variety of head and neck restraints) and energy-absorbing racetrack barriers. These approaches are discussed in a new module regarding how STEM practitioners have applied their skills to developing safer racing practices. The topic used to develop a design project for students (grades 6-12) was "energy-absorbing vehicle structures" (Hylton, 2009). For all drivers in the top racing series (e.g., the Formula One Grand Prix Circuit, Indy Cars that compete in Indianapolis 500, and the Car of Tomorrow (COT) stock cars which compete in the top NASCAR series) the use of energy-absorbing structures has become key to keeping them safe.

Learning From Previous Crashes

A great demonstration of the benefits resulting from energy-absorbing safety structures can be seen in Michael McDowell's qualifying crash at the Texas Motor Speedway in 2008. McDowell lost control of his car and crashed head-on into the outer retaining barrier of the track at an estimated 165 mph. Although the car was destroyed, as shown in Figure 2 (SpeedTV, 2008), he managed to walk away, and less than 24 hours later he qualified for the same race in another car. This crash is noticeably more severe than the crash that killed Dale Earnhardt (only a few years earlier). The difference in severity in the two crashes is immediately obvious to the students who are exposed to this motorsports safety material.

Figure 2. Michael McDowell's Texas Motorspeedway crash in 2008 (SpeedTV, 2008).

This discussion opens the door to several STEM concepts, beginning with a discussion of kinetic energy, which is equal to one-half mass times velocity squared. Students are asked to consider how the ever-increasing speeds of racecars have made it more challenging to protect the driver because of the increase in the vehicle's energy. The fact that applied work can offset energy is introduced in the context of the Law of Conservation of Energy. Work is calculated from an applied force over a distance. Students are asked to consider a way to examine the post-crash remnants of McDowell's car and estimate the force of the impact. With a little guidance, they recognize that the car is noticeably shorter after the crash. The crash resulted in a significant shortening of the front end of the car. Additionally, a review of the crash film shows deformation of the safer barrier wall that the car hit. The sum of the distance the wall deflected and the distance the center of gravity of the car moved during the shortening of the chassis can be used to estimate the distance over which the impact force was applied. Mathematical problem-solving skills are then exercised to estimate the amount of force that the car experienced during the crash. This is the sort of connectivity between real-world issues, science concepts, and mathematics skills that have previously piqued the interest of secondary school students and helped them appreciate their math and science training (Otoupal & Hylton, 2005). As a result, students improved in both their understanding of simple engineering technology concepts as well as their execution of math and science related problem-solving skills (Otoupal & Hylton, 2009). This is one of the main objectives of improving STEM education.

Project To Reinforce Energy-Absorbing Concepts

By performing parametric studies examining the results of this process, students can clearly see how the force that must be absorbed by the vehicle is related to the "crushability" of the structure. In other words, if the car can be intentionally designed to crush in a controlled manner during a crash, the structure is capable of absorbing more energy, thus reducing the forces transmitted to the occupant's body. Students are then given the objective of a designing their own energy-absorbing concept for a crash-test vehicle. The need to conceptualize, design, fabricate, and construct a vehicle capable of protecting a passenger (in this case an egg) during a severe impact, is a challenge that they can easily relate to after discussions that have been described in this article. Armed with the new-found understanding of how motorsports safety structures are designed, students are provided with simple construction materials (e.g., balsa wood, poster board and glue). In addition, they have access to a test cart, which will carry their structures down the crash-test track. They are also supplied the egg that will serve as a fragile passenger during the testing.

Once completed, the crash-test vehicles built by the students are sent down a sloped track, allowing them to convert potential energy at the top of the hill to kinetic energy at the bottom (another tie to appropriate science concepts), as shown in Figure 3. Results are readily obvious, because a successful design yields an intact driver (egg) after the crash, as shown in Figure 4. A less successful design fails to provide adequate energy absorption and results in an injured passenger, or in this case, a broken egg, as shown in Figure 5. For obvious reasons, this testing should be done outdoors.

Figure 3. The start of a safety structure crash test (IUPUI Media Gallery).

Figure 4. A successful result of a safety structure crash test (IUPUI Media Gallery).

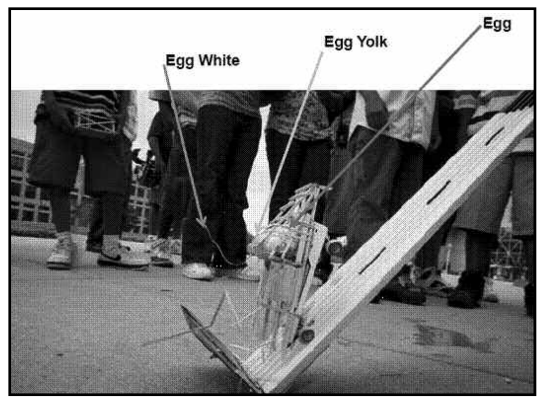

Figure 5. An unsuccessful result of a safety structure crash test (IUPUI Media Gallery).

Conclusions

1. After using motorsports-related educational modules in more than a dozen situations of various lengths and at various secondary school grade levels, the material has proven to be consistently popular with the student participants.

2. Assessment results from activities using these motorsports-related modules have indicated an increase in both awareness of STEM activities and careers, and growth in basic science and math skills.

3. When presenting elements of this work to secondary school teachers via STEM workshops, the teachers have consistently

indicated that the material would be easy to present in either a classroom or summer camp environment, even if they had no particular previous motorsports expertise.

4. Secondary school teachers have shown a strong belief that their students would react positively to the use of these motorsports-related materials in the classroom, which is capable of reaching across both gender and demographic lines.

5. Motorsports-related activities are an excellent way to connect with potential STEM students and assist them, through experiential learning, to further their math, science, design, and problem-solving skills.

Recommendations

1. Motorsports provides an exciting avenue for connecting students to STEM concepts and careers, but it has been mostly overlooked by the academic community. Based on the results of the modules developed at IUPUI, it is recommended that STEM educators consider integrating motorsports-based activities into their classroom.

2. The developers of these modules have disseminated information on the project to secondary school math and science teachers in only a localized area surrounding the university. It is recommended that mechanisms for broader dissemination be pursued.

3. As recommendations 1 and 2 are completed, it is recommended that a more thorough, and statistically based, analysis of student results be undertaken.

Dr. Pete Hylton is an Associate Professor in the Mechanical Engineering Technology Department at Indiana Univ. Purdue Univ. at Indianapolis.

References

Campbell, W. & Hylton, P. (2005, October) Teaming for the future with Purdue's Science Bound Initiative: A cooperative program involving university, secondary schools, and local industries to increase diversity in engineering and technology programs. *Proceedings of the 2005 Frontiers in Education Conference.* Indianapolis, Indiana.

Hylton, P. (2006, June) Teaching math with real world correlation. ASEE Workshop on K-12 Engineering Education, *2006 ASEE National Convention*, Chicago, IL.

Hylton, P. (2007, March) Let's go racing: Constructing a collegiate motorsports program, *Proceedings of the 2007 ASEE IL/IN Section Conference*, Indianapolis, IN.

Hylton, P. (2008, September) Guest editorial: Students and careers in motorsports. *Manufacturing Engineering.*

Hylton, P. (2009, August) Integrating motorsports into secondary education. PRISM Workshop, Rose-Hulman Institute of Technology, Terre Haute, IN.

Otoupal, W. & Hylton, P. (2005, September). Coupling math and engineering concepts in a K-12 classroom environment. *Proceedings of the 2005 ASEE/AaeE Global Colloquium.* Sydney, Australia.

Otoupal, W. & Hylton, P. (2006, June). Improving skills and attitudes in minority females training for engineering and technology careers. *Proceedings of the 2006 WEPAN Conference.* Pittsburgh, PA.

Otoupal, W. & Hylton, P. (2007, October). Stratification of attitudes and skill level as correlated with knowledge and self-confidence in a pre-engineering curriculum. *Proceedings of the 2007 Frontiers in Education Conference,* Milwaukee, WI.

Otoupal, W. & Hylton, P. (2009, Summer) Engaging secondary school students in pre-engineering studies to improve skills and develop interest in engineering careers. *The International Journal of Engineering Education*.

SpeedTV. (2008) [Photo illustration of the Michael McDowell, Texas Motor Speedway crash, 2008]. Retrieved 1/15/10 from http://nascar.speedtv.com/article/cup-video-big-qualifying-crash.

Teaching University-Level Technology Students via the Learning Preferences and Problem-Solving Approach.

Sophia Scott and Doug Koch

Abstract

This article focuses on how technology educators can challenge students to “think” about technical problems. A key aspect of success in quality problem solving is understanding learning preferences and problem-solving approaches. The Learning Style Inventory (LSI) can be used to assess an individual’s ideal way to learn, in essence, a person’s learning preference (Kolb, 1984). It also can be beneficial to understand how students approach problems. The Kirton Adaption-Innovation Inventory (KAI) can be used to measure an individual’s problem-solving approach (Kirton, 1999). The purpose of this study was to determine the most effective way to teach university-level technology students to solve problems, according to their learning preferences and problem-solving approaches. The results of the study indicated that a majority of the technology students had a combination of learning preferences. The next highest percent and frequency of the students’ learning preferences was accommodating. In addition, the students in this study were both adaptive and innovative in their problem-solving approaches. One way to effectively teach problem solving to university-level technology students is to form teams of students whose members have differing learning preferences and approaches. Moreover, educators can provide learning activities that address the phases of the learning cycle and the ways in which students like to approach problems.

Introduction

The ever-changing technical work environment requires students to think fast and solve complex global problems. It is estimated that the root of problems in many organizations is a result of ineffective thinking (Wiele, 1998). Employers depend on technology educators to develop quality thinkers. Technology educators aim to give students a “high tech” education. This “high tech” education often means skills in computer-aided drafting, robotics, telecommunications, and quality assurance tools. However, are educators challenging students to “think” about technical problems? Starkweather (1997) argued that educators teach students to use equipment, but they often fail to teach technical problem solving, which is a higher order thinking skill. Williams (2001) agreed, acknowledging that teachers should focus on how to think rather than what to think. Each individual has a preference to his or her thinking. The Learning Style Inventory (LSI) can be used to assess an individual’s ideal way to learn, in essence, his or her learning preference (Kolb, 1984). Another measure of thinking is the way in which students approach problems. The Kirton Adaption-Innovation Inventory (KAI) can be used to assess a person’s approach to solving problems (Kirton, 2000). Understanding learning preferences and problem- solving approaches can help students to become quality thinkers and problem solvers. Currently, there is little research on learning preferences and problem-solving approaches among university-level technology students.

Purpose of the Study

The purpose of this study was to determine the most effective way to teach university-level technology students problem solving according to their learning preferences and problem-solving approaches. In order for students to make the most of their education, understanding their learning preference and approach to problem solving is essential. The research questions for this study are as follows:

1. What is the learning preference of technology students enrolled in an Industrial Engineering Department at a Midwestern university?

2. What is the problem-solving approach of technology students enrolled in an Industrial Engineering Department at a Midwestern university?

3. What is the most effective way to teach university-level technology students problem solving based on their preferences and approaches?

The data gathered in this study can help students and educators understand problem solving and the way in which they prefer to learn and approach problems. The results of this study may influence the way in which educators teach university-level technology students to solve problems both inside and outside of the classroom.

Review of Literature

Learning style or preference is defined as the manner in which an individual prefers to learn. There has been a variety of learning style models, such as field independent/dependent (Messick, 1976), holist-analytical and verbal-imaginer (Riding & Cheema, 1991), Three-layer Onion Model (Curry, 1983), the LSI by Kolb (1984), the Productivity Environmental Preference Survey (PEPS), Price (1996) and Fleming and Mills' (1992) Visual, Aural, Read/write, and Kinesthetic (VARK). Learning style is considered separate from ability and has been widely researched in the educational setting. Price (2004) explained that learning styles are self-reported accounts of an individuals' preferences for and perceptions of how they process information. In other words, learning styles predict the way in which learners want to learn and solve problems. One of the most used instruments in an educational setting is the LSI, which was used in this research.

Learning Style Inventory

Kolb (2007) observed that individuals learn in different ways and understanding one's own preference of learning can be beneficial in problem solving. Kolb (1984) created the LSI to assess an individual's preference to learning. One of the purposes of the LSI is to serve as an educational tool to increase individuals' understanding of the process of learning and his/her unique individual preference to learning. Another purpose of the LSI is to provide a research tool for investigating experiential learning and the characteristics of individual learning preferences. The scores on the LSI determine one of the four learning modes:

- Concrete/Experience (CE): likes to learn from specific experiences, relating to people, and is sensitive to feeling and people.

- Reflective/Observation (RO): likes to learn by reflecting; carefully observes before making judgments, views issues from different perspectives, and looks for the meaning of things.

- Abstract/Conceptualization (AC): likes to learn by thinking; analyzes ideas logically, plans systematically, and acts on the intellectual understanding of a situation.

- Active/Experimentation (AE): likes to learn by doing; shows the ability to get things done, takes risks, and influences people through action (Kolb, 2007, p. 5).

Each of these learning modes creates the four phases of the learning cycle. When technology students cycle through the four phases, effective learning takes place. The four phases formulate an individual's learning preference. The four learning preferences follow:

- Diverging – combining experiencing and reflecting (CE & RO) learning preferences.

- Assimilating – combining reflecting and thinking (RO & AC) learning preferences.

- Converging – combining thinking and doing (AC & CE) learning preferences.

- Accommodating -- combining doing and experiencing (AE & CE) learning preferences-Figure 1 provides characteristics of each of the learning preferences (Kolb, 2007, p. 10).

Research shows that individuals who choose careers in science, technology, engineering, and math (STEM) tend to have converging and assimilating learning preferences (Kolb, 2007). Threeton and Walter (2009) found that post-secondary automotive technology students tended to have accommodating and converging learning preferences, indicating that students in

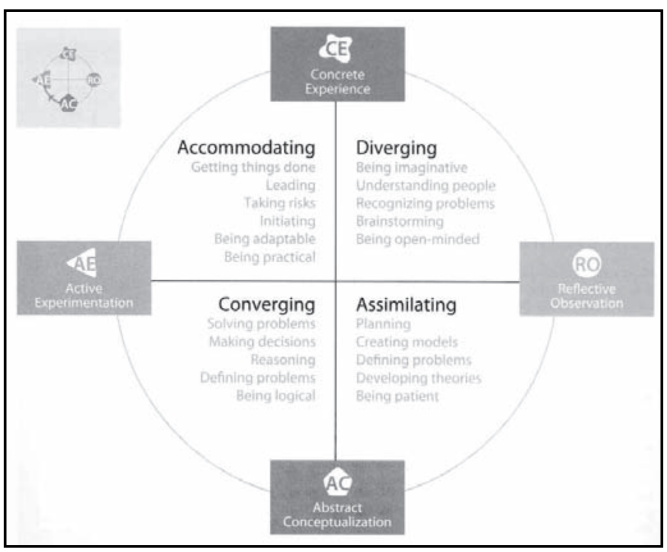

Figure 1. Learning preferences.

the study preferred hands-on activity and the practical use of ideas and theories. All of the learning preferences were represented in their study. In addition, a study using the PEPS found that teaching students according to their learning style does influence their learning. Similarly, all of these learning styles were represented in a recent study of the effectiveness of instructional methods based on learning style preferences of agricultural students conducted by Fazarro, Pannkuk, Pavelock & Hubbard (2009). Each learning preference has strengths in the problem- solving process. This research seeks to determine the learning preferences of university-level technology students.

Problem-Solving Approach

Technological problem solving involves higher order thinking and is a critical survival skill in today's progressive work environment. Government, business, vocational, and technology education leaders have increasingly called for more emphasis in the classroom on higher order thinking. Ernst (2009) agreed that higher order thinking and problem solving are essential for the technology professional and described technology students as perceiving themselves to be highly capable in their problem-solving ability. Furthermore, problem solving has been identified and promoted by many disciplines, including STEM. Technology students in particular need to be proficient in technical problem solving. Students have different abilities and approaches when solving problems. Students with the same ability can approach problems in different ways. Problem solving approaches are consistent, however, there are individual differences in the ways people prefer to move toward new ideas, manage change, and respond effectively to complex, open-ended opportunities and challenges. Olowa (2009) acknowledged that teaching students how to seek their own strategies and answers to problems rather than teaching students to memorize facts about the problem was an effective technique in enhancing problem solving. According to Adaption-Innovation (A-I) theory, individuals manage problems differently depending on their approach (Kirton, 2000). A-I is not considered a level of behavior. Behavior has several outside factors and approach is just one aspect considered at play. This research will focus on the approach that university-level students take when dealing with problems, not on problem-solving ability.

The KAI was created to measure the problem-solving approach of individuals (Kirton, 1999). The KAI places individuals on a continuum with extreme innovators at one end and extreme adaptors at the other end. The KAI score is not a dichotomy; there are no pure adaptors or innovators. There is no preferred score. Individuals can be classified as more adaptive or less adaptive and more innovative or less innovative, so scores need to be viewed in relation to the population mean or other individuals. The population mean is 95. Individuals with KAI scores that ranged from 32-95 were considered relatively adaptive, and individuals with scores that ranged from 96-160 were considered relatively innovative (see Table 1).

Kirton (2000) observed that differences in problem-solving approaches produced distinctive patterns of behaviors (see Table 2).

Table 1. Population Distribution of KAI Scores.

Innovators		Adaptors
96-110	Mild	95-80
111-124	Medium	79-65
125-139	High	64-50
140 or more	Very high	49 or less

Reproduced with permission. (Kirton, 2000, p. 39).

Occupations that tend to possess more adaptive individuals include plant and production managers, technical engineers, and programmers. This study aims to determine the learning preferences and problem-solving approaches of university-level technology students.

Methodology

This study included 95 students enrolled in the Industrial and Engineering Department at Southeast Missouri State University in the fall of 2008. The researchers selected five classes for the study. Class 1 (n = 15); class 2 (n = 9); class 3 (n = 24); class 4 (n = 36); and class 5 (n = 11). The majors of the participating students included construction management, interior design, technical graphics, industrial education, manufacturing technology, engineering technology, and telecommunications. Four students with undecided majors were included in the data. The study was approved by the University Research Involving Humans Subjects Committee.

Table 2. Characteristics of Adaptors and Innovators.

The Adaptor	The Innovator
Characterized by precision, reliability, efficiency, methodicalness, prudence, discipline, conformity.	Seen as undisciplined, thinking, tangentially approaching task from unsuspected angles.
Concerned with resolving residual problems thrown up by the current paradigm.	Could be said to search for problems and alternative avenues of solution, cutting across current paradigms.
Seeks solutions to problem in tried and understood ways.	Queries problems' concomitant assumptions: manipulates problems.
Reduces problem by improvement and greater efficiency, with maximum of continuity and stability.	Is a catalyst to settled groups, irreverent of their consensual views; seen as abrasive, creating dissonance.
Seen as sound, conforming, safe, dependable.	Seen as unsound, impractical; often shocks his opposite.
Liable to make goals of means.	In pursuit of goals, treats accepted means with little regard.

Reproduced with permission (Kirton, 2000, pp. 10-11).

Instruments

All participants were asked to complete the LSI and the KAI. The researchers administered and scored the instruments in two class sessions in the third and fourth week of the fall semester of 2008.

The Learning Style Inventory. The Learning Style Inventory (LSI) is a statistically reliable and valid 12-item assessment tool, developed by Kolb (1984). Subjects rank their preferences on each question from 1 to 4, with 1 being the least way they like to learn and 4 being the best way they like to learn. From the rankings, a total score was calculated.

Kirton Adaption-Innovation Inventory. The KAI is described as a self-reporting 33-item questionnaire with scores ranging from 32-160 (Kirton, 1999). The KAI asks the student the degree of difficulty (very hard to very easy) it would be for him or her to maintain the statement consistently over a long time.

Results

The purpose of this study was to determine the most effective way to teach university- level technology students problem solving according to their learning preferences and problem approaches.

Results of research question 1: *What is the learning preference of technology students enrolled in an Industrial Engineering Department at a Midwestern university?*

Of the 95 students who participated in the study, 70 students successfully completed the LSI for a 74% response rate. Forty-nine males and 21 females, ranging in age from 18-50, participated in the study. Table 3 displays the participants LSI mode scores.

A majority of the participants in this study had combination learning preferences. The next highest percent and frequency of the students learning preferences was accommodating.

Table 3. LSI Mean and Standard Deviation Mode Scores of Technology Students.

	Mean	SD
Abstract/Conceptualization (AC)	29.18	6.50
Concrete/Experience (CE)	29.86	8.86
Active/Experimentation (AE)	31.30	8.99
Reflective/Observation (RO)	30.46	6.84

Table 4. Learning Preference Frequency and Percentages of Technology Students.

	Frequency	Percentage
Diverging	8	11
Assimilating	8	11
Converging	5	7
Accommodating	12	17
Combination	37	54
Total	70	100

The results indicated that the technology students in this study majoring in technology fields did not correspond with converging and assimilating learning preferences typical in STEM fields.

Results of research question 2: *What is the problem-solving approach of technology students enrolled in an Industrial Engineering Department at a Midwestern university?*

Of the initial 95 students asked to participate in the study, 81 successfully completed the KAI for an 85% response rate. Twenty females and 61 males, ranging from the age of 18-50, participated. The KAI scores ranged from 66-133 (see Table 5).

The mean score of the technology students was 96, which is close to the population mean of 95. In addition, this study is consistent with the scores for engineering and technology careers, which typically range between 95 and 97.

Results of Research Question 3: *What is the most effective way to teach university-level technology students problem solving based on their preferences and approaches?*

Table 5. KAI Scores.

	N	Range	Mean Score	Stand. Dev.
Adaptive	41	66-95	86	8.22
Innovative	40	96-133	106	7.98
Total	81	66-133	96	12.8

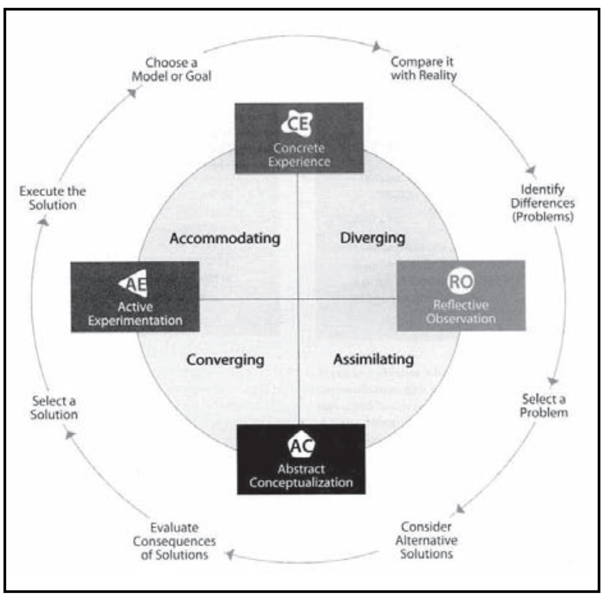

Figure 2. Learning preferences and the problem solving process.

Problem solving and learning preferences.

The strengths of a student's learning preferences influence his or her problem solving skills (see Figure 2). Figure 2 shows a modified problem-solving model and links the steps of the problem-solving model to learning preferences. For example, diverging preferences may prefer and excel at problem identification; assimilating preferences at problem selection and seeking alternatives; converging preferences at problem evaluation and selections; and accommodating preferences at problem evaluation and execution. The most effective way to teach problem solving may be to make sure that the students' cycle through the learning preference phases and are put in teams with students who vary in their learning preferences.

The technology students in this study were more accommodating, indicating that they would be most successful in evaluating and implementing the problem. A majority of the technology students in this study has combination learning preferences, signifying that they may excel at problem solving because they cycle through the learning phases.

In terms of education in general, diverging learning preferences prefer to look at situations from different perspectives and like to develop alternative possibilities; assimilating preferences tend to look at a large framework of ideas and integrate information into theories or models; converging preferences enjoy gathering information to solve problems and like to bring ideas together; and accommodating preferences tend to put ideas into action and adapt to changing circumstances. The majority of technology student in this study had a combining or balancing learning preference, indicating that they may be comfortable with a variety of learning modes.

Problem solving and problem-solving approach.

The problem-solving approach also influences students' problem-solving skills. Adaptors prefer their problems to be associated with more structure, often using the rules to stay within the current paradigm. Innovators, in contrast, prefer solving problems with less structure and tend to abandon the current paradigm. Table 6 shows the characteristics of adaptor and innovators in problem solving.

The technology students in this study were both adaptive and innovative, indicating that if partnered with someone with the opposite

Table 6. Characteristics of Adaptors and Innovators in Problem Solving.

The Adaptor	The Innovator
Tend to accept the problems as defined with any generally agreed constraints.	Tend to reject generally accepted perception of problems and redefine it.
Generally, early resolutions of problems, limiting disruption and immediate increased efficiency are important to them.	Tend to be less concerned with immediate efficiency, looking to possible long-term gains.
Prefer to generate a few relevant and acceptable solutions aimed at "doing things better."	Prefer to produce numerous ideas, some of which may not appear relevant or be acceptable to others.
Typically have easy solutions to implement.	Typically solutions result in "doing things differently."

Reproduced with permission (Kirton, 2000, p. 4).

approach, they would be successful in problem solving. Again the most effective way to teach problem solving to technology students may be to team students with individuals who use different problem-solving approaches, so the strengths of the approaches can prevail. In terms of education in general, adaptors prefer well-established lesson plans and like to go in depth in the lesson. Innovators, on the other hand, prefer less structure. They like to learn a breadth of information.

Discussion & Implication

Employers rely on technology educators to develop and promote technical problem-solving skills in students. Problem solving is a vital component of most careers, especially those in technical fields. Wiele (1998), Williams (2001), Starkweather (1997), and many others have pointed out the importance of being able to successfully solve problems. Previous studies show that individuals in STEM fields tend to have converging and assimilating learning preferences. The results of this study did not yield similar outcomes as the previous studies. The technology students in this study had combination learning preferences followed by accommodating, indicating that students who had combination learning preferences tended to work through the learning phases and progress through the problem-solving cycle. Accommodating students like to get things done and tend to enjoy leading, taking risks, initiating, being adaptable, and being practical in solving problems. As educators, if we understand the learning preferences of students, we can better equip them with the skills to solve problems and to work with and learn from others who have different learning preferences. Threeton and Walter (2009) caution educators to not rely on one teaching technique to reach the diverse learning preferences of technology students. They recommended adopting various instructional techniques and activities to educate students. It is also critical that students understand their own learning preferences. Many students do not have a firm grasp on how they prefer to learn. Students who know and understand their learning preferences may be able to better focus on their strengths and address their weaknesses when solving problems. Students who have a combined learning preference may also be able to better relate to and understand other preferences and therefore excel in problem-solving teams. In addition to learning preferences, an understanding of approaches to problem solving can affect technology students.

The approach, as measured by the KAI, of the studied technology students was typical of the population mean. The technology students in this study were a combination of adaptive and innovative in their approach to problem solving. This variation might reflect the diversity of the students. Having a good balance between innovative and adaptive approaches often provides a well- balanced approach toward various technical problems. Research has shown that students pursuing degrees in STEM areas tend to be more adaptive. This study contradicted previous studies revealing that the technology students in this study tended to be a combination of adaptive and innovative. For educators, understanding KAI can aid in lesson planning, because adaptors are more apt to prefer a step-by-step procedure for doing an assignment and innovators would prefer to have a process. Understanding KAI may also help with interpersonal conflict associated with team assignments and projects. Educators would be able to better accommodate students and better formulate teams consisting of different approaches. In addition, if the students and educators were aware of their approach to problem solving, they could be more efficient by focusing on their strengths or developing areas they are not as comfortable with. Furthermore, educators can provide learning activities that address the phases of the learning cycle and ways in which students like to approach problems.

Conclusions

The purposes of this study were to determine university-level technology students' learning preferences, problem-solving approach, and the most effective way to educate technology students' to solve problems based on their preferences and approaches. Students enrolled in the Industrial and Engineering Department completed the LSI and the KAI to assess their learning preference and problem-solving approach. The 70 students who completed the LSI had very close mode (AC, CE, AE, and RO) scores. Most technology students in this study had a combination learning preference with the next highest percentage an accommodating preference. Eighty-one of the students completed the KAI with a mean score of 96. This score is consistent with the population mean. The technology students in this study were a combination of adaptive and innovative and not typical of individuals in STEM fields.

Technology educators and students alike will benefit from knowing and understanding their learning preferences and problem solving approaches. Knowing and exposing students to the various preferences and approaches could make them better problem solvers and more adaptable to diverse situations. Even with the emphasis that is placed on problem solving, researchers know relatively little about the process, how to measure it, and how to best prepare students to be efficient and effective technical problem solvers. More research is needed on teaching problem solving that focuses on and isolates components and preferences of the problem-solving process. Additionally, more research needs to be conducted on the development of technical problem-solving teams formed in accordance to learning preferences and approaches to problem solving.

Dr. Sophia Scott is an Associate Professor in the Department of Industrial and Engineering Technology at Southeast Missouri State University, Cape Girardeau. She is a Member-at-large of Epsilon Pi Tau.

Dr. Doug Koch is an Assistant Professor in the Department of Industrial and Engineering Technology at Southeast Missouri State University. He is a member of the Beta Chi chapter of Epsilon Pi Tau.

References

Curry, L (1983). An organization of learning styles theory and constructs. Paper presented at the Annual Meeting of the American Educational Research Association (67th, Montreal, Quebec, April 11-15. (*ERIC Document Reproduction Service No. ED235185*)

Ernst, J. V. (2009). Contextual problem solving model origination. *Journal of Industrial Teacher Education, 46*(2). 27-47.

Fazarro, D. E., Pannkuk, T., Pavelock, D., & Hubbard, D. (2009). The effectiveness of instructional methods based on learning style preferences of agricultural students: A research tool for continuous improvement for faculty in Career and Technical Education (CTE) programs. *Journal of Industrial Teacher Education, 45*(3). 84-104.

Fleming, N. D., & Mills, C. (1992). Not another inventory, rather a catalyst for reflection. *To Improve the Academy, 11*, 137-155.

Kirton, M. J. (1999). *Kirton Adaption-Innovation Inventory manual.* (3rd ed). Berkhamsted, U.K.: Occupational Research Centre.

Kirton, M. J. (2000). (Ed.). *Adaptors and innovators: Styles of creativity and problem-solving.* New York: Routledge.

Kolb, D. A. (1984). *Experiential learning: Experience as a source of learning and development.* Englewood Cliffs, NJ: Prentice-Hall.

Kolb, D. A. (2007). *Kolb Learning Style Inventory*. USA: Hay Group.

Messick, S. (1976). *Personality consistencies in cognition and creativity.* San Francisco: Jossey-Bass.

Olowa, O. W. (2009). Effects of the problem solving and subject matter approaches on the problem solving ability of secondary school agricultural education. *Journal of Industrial Teacher Education, 46*(1). 33-45.

Price, G. E. (1996). *Productivity Environmental Preference Survey (PEPS): An inventory for the identification of individual adult learning style preferences in a working or learning environment.* Lawrence, KS: Price Systems, Inc.

Price, L. (2004). Individual differences in learning: Cognitive control, cognitive style, and learning style. *Educational Psychology, 24*(5). 681-698.

Riding, R. J, & Cheema, I. (1991). Cognitive styles: An overview and integration. *Educational Psychology. 11*. 193-215.

Starkweather (1997). Are we thinking to achieve? *The Technology Teacher,* 5-6.

Threeton, M. D., & Walter, R. A. (2009). Automotive technology student learning styles and their implications for faculty. *Journal of Industrial Teacher Education, 46(*3). 7-33.

Wiele, B. (1998). Different thinking styles and tools that harness them. *Otherwise: Paradigm Shift International.* Retrieved October, 2007, from http://www.parasift.com

Williams, E. (2001). Unlock those little grey cells. The Times Educational Supplement: Research focus, thinking skills. No. 4418. 22.

Students' Attitudes Toward STEM: Development of an Instrument for High School STEM-Based Programs

Mark Patrick Mahoney

Abstract

The intent of this study was to develop an instrument to measure the current level of attitude that students' exhibit toward STEM education. *The Concerns-Based Adoption Model, Taxonomy of Education Objectives – Handbook II,* and other pertinent instruments were utilized as sources of inspiration for the instrument. The selected items were submitted to a panel of experts representative of STEM education. Initial pilot testing refined the instrument through principal components analysis and Cronbach's alpha coefficients. The identified principal components aligned well with reviewed instruments. Reliability coefficients were strong for each of the principal components.

Results of the combined analyses led to revisions of the instrument prior to a larger comparative study – a known-group comparison. A self-identified STEM-based high school program and a conventional college-preparatory program were compared. Principal components analysis and Cronbach's alpha procedures were again applied to the data collected. The two samples were compared using three distinct independent variables – educational location, grade level, and gender. Each independent variable was analyzed for each principal component.

MANOVA procedures were utilized. Male students indicated a statistically significant more positive attitude toward STEM when compared to the female students for the independent variable of gender. The statistical significance was demonstrated specifically for the content areas of technology and engineering. The results of the data analysis supported the proposed hypothesis. Based upon extensive review of the varied data analysis procedures implemented, the students' attitudes towards the STEM instrument demonstrated positive examples of validity and reliability.

Introduction

In 1983, *A Nation at Risk* (National Commission on Excellence in Education [NCEE], 1983) established the resurgence for the science, technology, engineering, and mathematics (STEM) movement in education.

> The time is long past when American's destiny was assured simply by an abundance of natural resources and inexhaustible human enthusiasm, and by our relative isolation from the malignant problems of older civilizations. The world is indeed one global village. We live among determined, well-educated, and strongly motivated competitors. We compete with them for international standing and markets, not only with products but also with the ideas of our laboratories and neighborhood workshops. America's position in the world may once have been reasonably secure with only a few exceptionally well-trained men and women. It is no longer. (p. 10)

The influence of this report and its recommendations are echoed in the feverish development of national standards produced by academic organizations such as the National Council of Teachers of Mathematics (NCTM), the American Association for the Advancement of Science (AAAS), the National Research Council (NRC), and the International Technology Education Association (ITEA). It is within this process that we the history of STEM can be traced. NCTM (2000), AAAS (1989), NRC (1996) and ITEA (2000) documents all suggest the combination or integration of their respective subjects in an attempt to enhance student learning and STEM preparation.

This proposed subject integration has taken many forms since the overall arrival of standards. Programs, modules, packaged curriculums, and even charter schools have aligned themselves with proposed models of what a STEM educational program should represent. A report by the Academic Competitiveness Council ([ACC], 2007) indicates that there are up to 105 government-funded STEM education programs in the United States, ranging from kindergarten to post-graduate education. The report by the ACC also collected information regarding the cost associated with STEM education programs. Overall, estimates indicated a total government expenditure to exceed $3.12 billion during the 2006 fiscal year.

Evaluations of these programs were also collected and reviewed (ACC, 2007). Unfortunately, a majority of the evaluations were below the expectations of the council. In fact, those that did display potential still required revisions to add greater validity to the information provided. This is not a new occurrence. The National Science Foundation (NSF) has been revising its own grant procedures to account for this lack of efficient evaluation. Programs funded by NSF and other organizations have continued for years with government money without providing sufficient information or measurable influence upon the educational community (ACC, 2007).

Added to this condition is the limitless number of private industries that have produced and sold STEM educational products and curricula over the last 20 years. These varied items align themselves with national standards and suggest educational advancement in the form of problem solving, cooperative learning, and subject integration. However, very little research has been conducted regarding the degree of influence such products have had upon education or even student learning (Bottoms & Anthony, 2005; ITEA, n.d.; PTC-MIT Consortium, 2006). A more recent development is the creation of entire educational institutions devoted to STEM development. These schools are not vocational or career and technical institutions, but rather college preparatory programs designed to develop students' abilities and interest in STEM and STEM careers.

In 2005, the report T*apping America's Potential* (Business Roundtable) produced a summary of the concerns from a variety of local professional organizations. The report cited warnings in the form of a declining STEM-equipped population, increased foreign competition, low student interest toward engineering, low student achievement, and decline in research funding (Business Roundtable, 2005). The American Electronics Association (AeA) also shared their concern through the following statement in 2005: "America needs to recognize that future innovation is not predetermined to occur in the United States. Even if we were doing everything right, we still face unprecedented competition from abroad" (p. 3).

Large amounts of money and time have already been provided in the hopes that educational institutions will reinforce students' attitudes and abilities related to STEM. However, these donations have yielded little results as demonstrated by the continued reports being constructed each year demanding greater STEM investment and results. The development of an instrument that can accurately measure students' attitudes toward STEM is crucial to STEM-based programs, their intended outcomes, and the companies that aid in their implementation.

The Study

In late 2008, the development of an instrument capable of measuring students' attitudes toward STEM began. In order to create this new instrument, the research study was divided into three phases. Phase I consisted of the development of an instrument capable of measuring students' attitudes toward STEM. A panel of experts was assembled and utilized for initial face validity as well as item development. Phase II verified the instrument through pilot-testing and high school student focus group interviews. Results from the pilot test in addition to student responses were then used to revise the instrument.

Phase III completed the intended study by implementing the revised instrument at two high school settings; a conventional college-preparatory school and a STEM-based college-preparatory school. It was hypothesized that students enrolled in the STEM-based high school program would exhibit more positive attitudes toward STEM when compared to students in a conventional college-preparatory high school program. It was also hypothesized that students exposed to STEM education for a longer period of time would exhibit a more positive attitude toward STEM than students who were just entering the program. Finally, it was hypothesized that male students would exhibit a more positive attitude toward STEM than would female students. These hypotheses were tested in an attempt to provide the students' attitude toward STEM instrument with an additional example of construct validity.

Phase I: Instrument Development

To develop an instrument capable of measuring students' attitudes toward STEM, several existing instruments were reviewed. Many of those reviewed are very strong assessments as indicated by their reported statistics. One example is that of the affective instrument located in the *Trends in Mathematics and Science Study* (TIMSS). According to Chiu (2007), the TIMSS instrument provides a useful factorial model. Nevertheless, such analysis has come under fire for suffering "from a number of methodological inadequacies;" not measuring up "to those [instruments] that are now expected for these affective attributes by main stream researchers" (Fensham, 2007, p. 3).

Other instruments offered a strong basis for an instrument design, but these did not easily make the transition to a scale capable of measuring students' attitude in multiple subjects. *The Kuder Occupational Interest Survey, Form DD* (Zytowski, 1973, 1992, 1996), *Ohio Vocational Interest Survey* (1981), and the *Thurstone Interest Schedule* (Thurstone, 1947) are examples of these types of instruments. In order to construct an attitudinal instrument for STEM, varied affective based documentation, including associated instruments, were sought and reviewed.

To complicate this search, an abundance of definitions can be found in any document or text whose author attempts to grapple with attitude and attitudinal measures. "The concept [attitude] has been plagued with ambiguity," so much so that researchers "may find it difficult to grasp precisely how they [the varied definitions of attitude] are conceptually similar to or different from one another" (Rokeach, 1968, p. 110). The assortment of available definitions has been both a strength and a weakness in the creation of attitudinal instruments.

> The meaning of a concept is defined in terms of its relations to other constructs in a theoretical network. Thus two investigators may offer different explicit definitions of attitude. However, if their attitude theories revealed that they agreed on the relationships between attitude and other concepts. . . it could be argued that the term "attitude" has the same meaning for the two investigators." (Fishbein and Ajzen, 1975, p. 5). It is for this reason that many of the definitions may be interchangeable (Rokeach, 1968).

Schwarz (2007) stated that a "person's attitude is 'stable' when the person provides similar attitude reports at different times and/or in different contexts" (p. 6). This is exemplified when a judge passes similar judgment on cases that share similar attributes and conditions according to the information provided. If the context is the same, the attitude should be stable. If the context of the judgment should change (i.e., by a change in information or condition), the initial attitude demonstrated will no longer fit the model. By this example, it is assumed that the attitude measurements and definitions should be specific to the variables and conditions for which it is to be implemented. If this is followed, then the established concept of attitude created for that situation should remain stable.

It was imperative in this study to establish a definition of attitude that is reflective of the variables and conditions for which it is to be implemented. Materials and instruments that could serve as forms of inspiration were sought and reviewed. An instrument of interest was the Concerns Based Adoption Model (CBAM); specifically the Stages of Concern (SoC)(Hall, 1974; Hall, George, & Rutherford, 1978). The CBAM model originally was used to understand how a person, specifically a teacher, reacted to a change in instruction or educational format presented during a professional development sequence. The concept was to be able to gauge how a person reacts to a presented change over the course of its implementation. The CBAM concept was closely related to the problem that is presented to a student when engaged with a STEM-based program. Is it possible to gauge how a student may react to a new educational material and format? Does a student accept or reject the change?

However, the CBAM documentation is not nearly enough to base an entire attitudinal instrument upon. To accomplish this, a more thorough review of affective characteristics was required. This would be provided by an established body of work directly associated with attitude and the entire *affective* domain: the *Taxonomy of Educational Objectives, Handbook II* (TEOII) by Krathwohl, Bloom, & Masia (1964).

The *affective* domain as established by Krathwohl and collegeaus is a broad and yet applicable interpretation of the subject. The purpose of the *affective* domain was to establish objectives that "emphasize a feeling tone, an emotion, or a degree of acceptance or rejection" (Krathwohl et al., 1964, p. 7). Terms that were discussed included "interest, attitude, values, etc." (p. 27). It was quickly discovered that definitions were "difficult to devise, and their meanings tended to drift into the connotations and denotations which these terms encompassed in common parlance" (p. 27). A more specific assembly of these characteristics would limit the use and flexibility of the objectives intended to be drawn from this taxonomy. It is for this reason that a combination of the *affective* taxonomy with the CBAM instrument was considered to be most beneficial.

Therefore, the CBAM and the TEOII were utilized as the inspirational models to create measurable categories specific to students' attitudes and their implications toward STEM. Both foundational pieces address key attributes vital to the concerns of the researcher and the desired instrument, the elements of progressive change within an individual and the affective characteristics of such progressive change. The categories were established by observable similarities between the CBAM and TEOII materials in conjunction with measuring the affective domain. A panel of experts in or related to the field of STEM and STEM education was assembled to review these items. Each expert was provided with the four preliminary categories created by the researcher. The list provided to the experts is displayed in Table 1.

Table 1. Student Attitude Toward STEM – Item Development.

Category	Associated Terms:
Awareness:	Interest, recognition, knowing, consciousness, attention, curiosity, concern
Perceived Ability:	Capability, skill, be able to, confidence, certainty, self-belief
Value:	Worth, significance, importance, usefulness, merit, regard
Commitment:	Pledge, dedication, devotion, potential, prospective, intention

Table 2. Student Attitude Toward STEM: Pilot Study Items.

Category	Associated Terms:
Awareness:	1. I like to read about: 2. My school offers courses in: 3. My school does not offer after school programs in: 4. I enjoy watching TV shows involving: 5. I do not want to learn more about: 6. I do not enjoy taking courses in: 7. Courses in [subject] are available to me 8. I dislike the challenge of: 34. I like:
Perceived Ability:	9. I am good at projects involving: 10. [subject] is difficult for me: 11. I perform well in [subject] courses: 12. I can not handle advanced courses in: 13. [subject] is simple: 14. I do not worry about taking tests in: 15. I struggle in [subject] courses: 16. I do not understand: 17. Homework in [subject] is easy:
Value:	18. [subject] is important 19. What I learn in [subject] has no value to me: 20. I believe there is a need for: 21. I need: 22. Learning [subject] will not help me: 23. [subject] is good: 24. I care about developments in: 25. [subject] is not worth my time to understand:
Commitment:	26. I would dislike more/advanced courses in: 27. I would like to participate in more after-school programs in: 28. I am curious about a career involving: 29. I am interested in advanced programs involving: 30. I have no interest in discovering new ways to apply: 31. [subject] is not a vital part of my perceived future: 32. I intend to further develop my abilities in: 33. I will continue to enjoy the challenge of:

After meeting with each of the panel members, the researcher created a list of 50 initial instrument items. Revisions and corrections were offered from these experts, and they were reviewed by the researcher. A final list of 34 initial items for each content area was assembled – 136 items total (see Table 2).

The next process was to formulate each item into a scale that could measure across the four content areas of STEM. A variation of a four-level Likert scale was created and implemented in an attempt to avoid central tendency bias. Each level of the scale was arranged to represent all four content areas of STEM. This was accomplished by placing each scale in what is referred to as an "item block" (see Figure 1).

Phase II: Pilot Study

Once the complete instrument was assembled, a high school within a local, metropolitan school district was contacted and used in an initial review of the instrument. The student sample was drawn from an accessible school population that was randomly selected from preexisting homerooms established by the high school administration (see Table 3).

Pilot Study Results

Three principal components were identified as a result of the principal components analysis: *interest, ability,* and *value*. According to the Cronbach's alpha calculations, each identified component indicated very high reliability with alpha ratings above .70 (see Table 4). A focus group of available students was conducted following the study. The students were asked to re-state the items in their own words to demonstrate item clarity and overall communication of the instrument. This was conducted to avoid certain aspects of measurement error. It was expected that these steps would provide greater content and face validity in addition to the computer-based data analysis.

Lastly, a Pearson product moment correlation was established between a semantic differential instrument (SEMDIFF) and the STEM instrument. The SEMDIFF instrument was also given to the participating students. The correlation was .58 (p = .001), indicating a significant, moderately positive relationship between the two instruments. Significance varied for each content area: science, r = .46, p = .013, technology, r = .41, p = .031, engineering, r = .50, p = .007, mathematics, r = .75 (p = .000). A collection of bi-polar pairs did not display discernable consistency toward either of the identified principal components. Data from items identified as questionable were removed prior to a second analysis – these were labeled as a modified SEMDIFF.

The Pearson product moment correlation between the overall modified SEMDIFF and STEM instruments was now .63 (p = .000), indicating a somewhat more significant and moderately positive relationship than the previous score of .58 (p = .001): r = .48, p = .010, technology, r = .40, p = .034, engineering, r = .63, p = .007, mathematics, r = .76 (p = .000). The correlation provided an example of concurrent validity for the Student

Question A	Most -------------- More -------------- Less -------------- Least			
I like:	S	S	S	S
	T	T	T	T
	E	E	E	E
	M	M	M	M

Figure 1. Student attitude toward STEM – Item block.

Table 3. Student Attitude Toward STEM – Pilot Study Collection Rates.

	Data Collection					
Grade Level	**Provided**	**% of School**	**Returned**	**%**	**Completed**	**%**
Ninth	21	22%	8	38%	8	38%
Tenth	18	23%	6	33%	6	33%
Eleventh	18	18%	9	50%	8	44%
Twelfth	17	17%	10	59%	9	53%
Total:	74	20%	33	45%	31	42%

Table 4. Student Attitude Toward STEM – Cronbach's Alpha Scores.

Content areas	Principal components							
	Overall		Interest		Ability		Value	
	Alpha	No. of items	Alpha	No. of items	Alpha	No. of items	Alpha	No. of items
Science	.94	29	.94	13	.95	10	.90	7
Technology	.91	34	.77	6	.92	11	.84	8
Engineering	.93	34	.90	13	.90	9	.82	8
Mathematics	.96	34	.76	6	.95	9	.89	7

CONTENT AREA						
bad	._______.	._______.	._______.	._______.	._______.	good
like	._______.	._______.	._______.	._______.	._______.	hate
loathe	._______.	._______.	._______.	._______.	._______.	welcome
interesting	._______.	._______.	._______.	._______.	._______.	dull
pleasant	._______.	._______.	._______.	._______.	._______.	foul
optimistic	._______.	._______.	._______.	._______.	._______.	pessimistic
hard	._______.	._______.	._______.	._______.	._______.	soft
light	._______.	._______.	._______.	._______.	._______.	heavy
feminine	._______.	._______.	._______.	._______.	._______.	masculine
severe	._______.	._______.	._______.	._______.	._______.	lenient
weak	._______.	._______.	._______.	._______.	._______.	strong
tenacious	._______.	._______.	._______.	._______.	._______.	yielding
active	._______.	._______.	._______.	._______.	._______.	passive
excitable	._______.	._______.	._______.	._______.	._______.	calm
cold	._______.	._______.	._______.	._______.	._______.	hot
complex	._______.	._______.	._______.	._______.	._______.	simple
easy	._______.	._______.	._______.	._______.	._______.	hard
slow	._______.	._______.	._______.	._______.	._______.	fast

Figure 2. Student attitude toward STEM – Semantic differential.

Attitude Toward STEM instrument in its use as a measure of the construct of attitude.

A complete item analysis was conducted for each item for the instrument. Due to the brevity of this document, this analysis has been omitted. However, based upon the collective review of data, 24 items for each content area were compiled for the revised instrument and used in the comparison study: 96 items total. The panel of experts was again contacted and used to review the 24 items for each content area (see Table 5).

Phase III: Known-Group Comparison Study

After completing the initial review of the STEM attitude instrument, a Known-Group Comparison Study was performed. Two high schools within a local metropolitan area were used. One high school consisted of a publicly identified STEM-based program, and the other high school consisted of a state-defined college-preparatory program. Two grade levels – the ninth and eleventh grades – from each high school were provided the instrument packets. The collection rate is provided in Table 6. Table 7 describes the distribution of participants by school, grade, and gender in the known-group comparison sample.

Known-Group Comparison Results

A second principal components analysis was conducted. This was required because of revisions to the instrument. Again, three principal components were identified by the researcher for all content areas: *interest, ability*, and *value*. A high percentage of variance was explained by the three identified principal components for each content area: science = 69%, technology = 64%, engineering = 73%, and mathematics = 68%.

Possible intercorrelations between the identified principal components were demonstrated by shared item loadings. Item loadings for all content areas and initial item design intentions were considered prior to assigning principal components. The possibility of intercorrelations between principal components was momentarily

Table 5. Student Attitude Toward STEM – Revised Instrument Items.

Category	Associated Terms:
Awareness: (Initial Interest)	1. I do not like 2. I enjoy learning about 3. I am curious about 4. I am not interested in 5. I like 6. (subject) is appealing to me
Perceived Ability:	
	7. (subject) is difficult for me 8. I do well in 9. I am not confident about my work in 10. I have a hard time in 11. Assigned work in (subject) is easy for me 12. I can not figure out
Value:	
	13. (subject) is important to me 14. I feel there is a need for 15. I do not need 16. It is valuable for me to learn 17. (subject) is good for me 18. I do not care about
Commitment: (Long-term interest)	19. I will continue to enjoy 20. I am not interested in a career involving 21. I am interested in alternative programs in 22. I would like to learn more about 23. I do not wish to continue my education in 24. I am committed to learning

Table 6. Student Attitude Toward STEM – Known Group Comparison Collection Rate.

School	Grade Level	Distrib.	% of Pop.	Returned	%	Completed	%
STEM-based high school	Ninth	92	100%	37	40%	35	38%
Total	Eleventh	78	100%	26	33%	26	33%
		170		63		61	
College-preparatory high school	Ninth	118	37%	52	44%	48	41%
Total	Eleventh	90	31%	36	40%	35	39%
		208		88		83	
Total:		378		151	40%	144	38%

overlooked so that further statistical analysis could be performed. This decision was approved for the sake of the study and its preliminary character. Future studies with larger sample sizes and a refined Student Attitude Toward STEM instrument will appropriately address this concern.

Internal reliability was again estimated though the use of Cronbach's alpha internal consistency coefficient. The complete collection of items used in the pilot study provided very strong alpha ratings for each of the content areas (see Table 8).

According to the results of the data analysis, the STEM-based high school students did not exhibit a statistically significant more positive attitude toward the content areas of STEM when compared to the college-preparatory high school students. It was anticipated that the STEM-based high school students would show a more positive attitude due to the school programs' specific focus and dedication toward STEM, as indicated by public documentation. This proposed difference would have provided an example of construct validity for the Student Attitude Toward STEM instrument. Though this result was not anticipated, it was not believed to

Table 7. Distribution of Gender and Grade Level by High School in the Data Analysis Sample.

	STEM-based high school		College-preparatory high school		
	Females	Males	Females	Males	Total
Ninth-grade	17	18	20	28	83
Eleventh-grade	14	12	22	13	61
Total	31	30	42	41	144

Table 8. Student Attitude Toward STEM – Cronbach's Alpha Scores.

Content	Principal components							
	Overall		Interest		Ability		Value	
	Alpha	No. of items	Alpha	No. of items	Alpha	No. of items	Alpha	No. of items
Science	.96	23	.95	9	.90	6	.91	8
Technology	.95	23	.93	9	.88	6	.90	8
Engineering	.97	23	.95	9	.90	6	.94	8
Mathematics	.96	23	.94	9	.91	6	.91	8

Note. Item 22 was removed from the analysis, resulting in an overall total of 23 items.

have negative implications for the student attitude toward the STEM instrument. Variables or factors that could have influenced this outcome – positively or negatively – have not yet been identified or investigated.

Interestingly, a statistically significant more positive attitude was demonstrated by the college-preparatory high school students when compared to the STEM-based high school students for the content area of mathematics. Review of this analysis could allow for the determination that both high school programs support similar positive attitudes for the content areas of science, technology, and engineering. Also, it may be determined that the college-preparatory high school is supporting a more positive student attitude for mathematics when compared to the STEM-based program students.

Similarly, the students in the eleventh grade did not exhibit a statistically significant more positive attitude for the content areas of STEM when compared to the students in the ninth grade. Like the previous hypothesis, an unexpected and opposite result was demonstrated by the analyses. A statistically significant more positive attitude was demonstrated by the ninth-grade students when compared to the eleventh-grade students for the content area of mathematics. Review of this analysis could allow for the determination that students at both grade levels exhibit similar levels of attitude for the content areas of science, technology, and engineering. It could also be determined that the ninth-grade students had more positive attitudes for STEM than did eleventh-grade students for the content area of mathematics.

Lastly, the male students did indicate a statistically significant more positive attitude for STEM when compared to the female students. The statistical significance was demonstrated specifically for the content areas of technology and engineering. The results of the data analysis supported the proposed hypothesis for the content areas of technology and engineering, and therefore they provided the Student Attitude Toward STEM instrument with an example of construct validity.

It was anticipated that the male students would provide a more positive attitude for STEM and STEM education due to the gender bias that has been traditionally associated with the STEM content areas. Though not statistically significant, an unexpected and interesting result was revealed in the analyses. Male students did not depict a statistically significant more positive attitude for STEM for the content areas of science and mathematics. This would imply that male and female students do not differ significantly regarding their attitudes for these two content areas.

Summary

This study was described as a critical tool for STEM education programs as well as the organizations that support them. The instrument was developed to indicate students' attitudes toward STEM, so that educational institutions that are implementing a STEM-based program can ascertain if their program is having the desired influence on their students.

Levels of student attitude were accurately defined and identified through review of pertaining literature, utilization of a panel of experts, as well as appropriate statistical analysis. The initial analyses demonstrated the foundational construct and content validity for the student attitudinal instrument. They were identified as *interest, ability,* and *value.* Items required to address each category of student attitude were defined and identified through review of pertaining instruments, a panel of experts, a student focus group, and appropriate statistical analysis. The combined analyses applied to the instrument items provided strong indications of reliability.

Reliability coefficients collected from the applications of the two versions of the Student Attitude Toward STEM instrument indicated Cronbach's alpha scores above what was anticipated based on established attitudinal instruments; coefficient of .92 alpha. This far exceeded the .70 alpha anticipated from the established research. The Pearson product moment correlation between the Student Attitude Toward STEM instrument and the SEMDIFF indicated an overall moderately positive significant relationship between the two instruments ($r = .63$, $p = .000$). This provided the Student Attitude Toward STEM instrument used for the pilot study with a viable source of concurrent validity.

The instrument was effective in identifying differences between male and female students. The instrument did not detect significant differences between the schools or the grade levels. The lack of detection of difference may not be a deficiency of the instrument, but it could be due to sensitivity provided by small and exclusive samples. Another possible indication could be the actual lack of difference between the independent variable groups of school and grade level. Larger and more varied samples should provide enough information to resolve these concerns.

Further review of the instrument and its associated items will continue through the exploration of larger and varied samples. It is expected that students' attitudes toward the STEM instrument will be exposed to as much research and revisions as are available until it becomes an applicable and reliable attitudinal measurement device. Recommendations for future research include, but are not limited to the following:

- Repeat the study with a larger and more varied sample size.
- Use longitudinal application of the instrument to previously assessed students.
- Conduct individual student interviews following submission of the instrument.
- Review the combined influence of independent variables.
- Investigate other possible independent variables.

An official timeline has not been established for completion of the instrument. Review of other attitudinal instruments revealed that the development and research required for a substantial attitudinal instrument is almost never complete and could continue on indefinitely. This study was an initial step toward what could be a lifelong development of an instrument to measure students' attitudes toward STEM. It was an imperative step in providing what could be a valuable tool for STEM-based educational programs as well as organizations that support them.

Dr. Mark Patrick Mahoney is currently an assistant professor within the Technology and Industrial Arts Department at Berea College in Berea, Kentucky. He is a member of Alpha chapter of Epsilon Pi Tau.

References

Academic Competitiveness Council [ACC]. (2007). *Report of the academic competitiveness council.* Washington, DC: U.S. Department of Education.

American Association for the Advancement of Science[AAAS]. (1989). *Science for all Americans: A Project 2061 report on literacy goals in science, mathematics, and technology.* Washington, DC: Author.

American Electronics Association[AeA]. (2005). *Losing the competitive advantage: The challenge for science and technology in the United States.* Washington, DC: Author.

Bottoms, G., & Anthony, K. S. (2005). *Project lead the way: A pre-engineering curriculum that works: A new design for high school career, technical studies.* Atlanta, GA: Southern Regional Education Board.

Business Roundtable. (2005, July). *Tapping America's potential: The education for innovation initiative.* Washington, DC: Author.

Chiu, M-S. (2007). Mathematics as mother/basis of science in affect: Analysis of TIMSS 2003 Data. *Proceedings of the 31st Conference of the International Group for the Psychology of Mathematics Education, Taiwan, 2*, 145-152.

Fensham, P. (2007). Interest in science: Lessons and non-lessons from TIMSS and PISA. In Pinto, R. & Couso,D. (Eds.), *Contributions from science education research* (pp. 3-10). Dordrecht, The Netherlands: Springer.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research.* Reading, MA: Addison-Wesley.

Hall, G. E. (1974). *The concerns-based adoption model: A developmental conceptualization of the adoption process within educational institutions.* Austin: Research and Development Center for Teacher Education, University of Texas.

Hall, G. E., George, A. A., & Rutherford, W. L. (1978). *Stages of concern about the innovation: The concept, verification, and implications.* Austin: University of Texas.

International Technology Education Association [ITEA]. (n.d.). *Engineering by design: A standards-based model program.* Retrieved January 24, 2008, from http://www.iteaconnect.org/ EbD/ebd.htm

International Technology Education Association [ITEA]. (2000). *Standards for technological literacy: Content for the study of technology.* Reston, VA: Author

Krathwohl, D. R., Bloom, B. S., & Masia, B.B. (1964). *Taxonomy of educational objectives: The classification of educational goals, handbook II.* New York: McKay.

National Commission on Excellence in Education[NCEE]. (1983). *A nation at risk: The imperative for educational reform: A report to the nation and the Secretary of Education, United States Department of Education.* Washington, DC: Author.

National Council of Teachers of Mathematics [NCTM] (2000). *The principles and standards for school mathematics.* Reston, VA: Author

National Science Foundation [NSF]. (n.d.). *National science foundation: Where discoveries begin: About funding.* Retrieved February 7, 2008, from http://www.nsf.gov/funding/ aboutfunding.jsp.

National Science Foundation [NSF]. (n.d.). *National STEM education distributed learning (NSDL): Definition of STEM.* Retrieved May 25, 2000, from http://www.nsf.gov/pubs/ 2009/nsf09531/nsf09531.html

Ohio vocational interest survey. (1981). New York: The Psychological Corporation.

PTC-MIT Consortium. (2006). *Preparing for the perfect storm.* Washington, DC: National Academy of Engineering.

Rokeach, M. (1968). *Beliefs, attitudes, and values: A theory of organization and change.* San Francisco: Jossey-Bass.

Schwarz, N. (2007). Attitude construction: Evaluation in context. In B. Gawronski (Ed.), What is an attitude? *Social Cognition, 25*(5), 638-656.

Thurstone, L.T. (1947). Thurstone Interest Schedule: Manual. New York: Psychological Corporation.

Zytowski, D. G. (1973). Contemporary approaches to interest measurement. *Minnesota library on student personnel work* (Vol. 10). Minneapolis, MN: University of Minnesota Press.

Zytowski, D. (1992, November). Three generations: The continuing evolution of Frederic Kuder's interest inventories. *Journal of Counseling & Development, 71*(2), 245-248. Retrieved May 13, 2008, from Professional Development Collection database.

Zytowski, D. (1996, December). Three decades of interest inventory results: A case study. *Career Development Quarterly, 45*(2), 141-148. Retrieved May 13, 2008, from Professional Development Collection database.

Re-enJEANeering STEM Education: Math Options Summer Camp

Vibhuti Dave, Dawn Blasko, Kathryn Holliday-Darr, Jennifer Trich Kremer, Robert Edwards, Melanie Ford, Lucy Lenhardt, and Barbara Hido

Abstract

Although the number of women majoring in engineering and engineering technology has increased in the last few decades, percentages lag behind those in other STEM disciplines. Young women often have misperceptions about the nature of engineering, and that leads to lack of interest. Engineering is often seen as men's work. They do not understand how engineers can have a positive impact on society (Hersh, 2000). Math Options Summer Camp, a program that has been conducted during the past two summers, addresses these issues. The week-long camp was designed for girls entering ninth and tenth grade when they still have time to add math and science courses to their schedules. Unlike other summer STEM initiatives, this camp focused on the use of technology: an integrated jean bag project was used to introduce campers to different areas of engineering (electrical, mechanical, and plastics) in hands-on lab-based modules. In this article the camp is described and data on campers' assessments of their experiences is provided. Workshop evaluations showed that the campers particularly enjoyed using technology in the labs and came away from the camp with a broader understanding of STEM careers.

Introduction

The demand for workers in the fields of science, technology, engineering, and math (STEM) is predicted to grow twice as fast as the overall rate of growth for workers in all occupations over the next five years in the United States (National Science Board, 2008). The question is: will there be enough people qualified to meet these demands? The National Center for Education Statistics predicts that the growth of undergraduate enrollments in the STEM fields over the next five years will only attribute to half of the demand for workers (U.S. Department of Education Institute of Education Sciences NCES, 2008). It is evident that something needs to be done to encourage young adults to enter these fields in order to prevent the United States from facing a severe shortage of engineers and scientists in the near future.

One way of addressing the issue is to solve the problem of underrepresentation of women in many of the STEM fields. Table 1 shows the results of a 20-year study by the National Science Foundation (NSF, 2008). Women receiving undergraduate degrees are well represented in science, but they have a long way to go in technology, math, and engineering. Although the number of women in STEM fields is increasing overall, the numbers for math (26.8%), computer science (26.8%), and engineering (19.5%) are still woefully low. It is quite obvious that steps need to be taken to significantly increase the number of women in engineering and technology.

Table 1. Women as a Percentage of Undergraduate Degree Recipients by STEM Major.

STEM major	1986	1996	2006
Biological, agricultural sciences	45.5	50.2	59.8
Earth, atmospheric, ocean sciences	22.3	33.3	41.2
Mathematics, computer sciences	38.8	33.9	26.8
Physical sciences	29.8	37.0	42.4
Engineering	14.5	17.9	19.5

Many factors contribute to the lack of women in the STEM fields, particularly in engineering and technology. One factor is that some girls find the requirements for higher level math and science to be intimidating while in middle school. This may result in a loss of confidence in their ability to do well in these areas, which in turn leads to a lack of interest in pursuing engineering as a career option. Engineering, has been a male-dominant profession, and it is often viewed as a masculine profession (Hughes, 2002). Young girls often prefer to pursue a career that might result in their helping people, and they may find it difficult to see engineering in that light (Hersh, 2000). Research has also shown that girls' awareness in this matter can be increased by exposing them to successful female role models (Haemmerlie & Montgomery, 1991; Plant, Baylor, Doerr, & Rosenberg-Kima, 2009) and by demonstrating that engineering has a positive impact on society.

Colleges and universities across the nation are looking at ways to increase the supply of qualified students coming out of high schools. A variety of STEM outreach programs have been created and developed to specifically target women and other underrepresented groups. Many such programs are one day long; the focus is to introduce young women and/or other underrepresented groups in several age groups to the STEM disciplines. Typically, these programs are comprised of introductory and closing sessions with several small-group activities, which are usually hands-on exercise sessions. Duke University's FEMMES (Females Excelling More in Math, Engineering, and Science) program for girls in 4th – 6th grades (Weston, Bonhivert, Elia, Hsu-Kim, & Ybarra, 2008), and the South Dakota School of Mines and Technology's E-Week GIRLS program for girls from middle school through high school (Karlin, 2005) are examples of such events. The E-Week Girl's program has been very successful in targeting girls from the rural regions of South Dakota. Additionally, Baylor University offers a one-day Girl Scout day camp for both Brownies and Juniors (Fry, Davis, & Shirazi-Fard, 2008).

Penn State Erie, The Behrend College (PSB), a stand-alone college of The Pennsylvania State University, has 4,400 students and is located in Erie, Pennsylvania. PSB organizes two 1-day programs that bring girls to campus for hands-on STEM activities. Women in Engineering was designed for tenth- and eleventh-grade girls and provides an introduction to engineering through hands-on workshop activities. Math Options Career Day was developed for middle school girls and is broadly focused on the importance of math in a wide variety of disciplines.

In addition to single-day programs, another popular vehicle for introducing girls to the STEM disciplines are week-long summer camps. One such example is the Science, Technology, and Engineering Preview Summer Camp for Girls (STEPS for Girls) organized by the University of Wisconsin-Stout that has run for more than a decade. This program specifically targets girls entering seventh grade. It is designed to introduce them to occupational opportunities in STEM and to encourage them to take appropriate math and science courses to prepare for those fields. The main focus is on manufacturing, and they spend the week tracking the manufacturing processes involved in producing a radio-controlled airplane (Bee, Puck, & Heimdahl, 2007). Grand Valley State University runs essentially the same STEPS program (Plotkowski, Sheline, Dill & Noble, 2008). The University of Arkansas has a summer day camp for middle school girls aimed at increasing their interest in STEM fields (Burkett, Small, Rossetti, Hill & Gattis, 2008). This is done through a series of hands-on activities throughout the week. All of the activities are designed to be both fun and educational. Projects range from 3D modeling of a simple box with a personalized lid to the programming of a robot.

The goal of this article is to describe a newly designed summer camp, known as Math Options Summer Camp, for tenth- and eleventh-grade girls, which was held at PSB in 2008 and 2009. This unique theme-based camp covers multiple engineering, engineering technology, and science majors. The camp was run in two distinct parts with the engineering and engineering technology portion in the mornings and the natural and social sciences in the afternoons. The article focuses on the engineering and technology sessions held in the morning. This portion of the camp was specifically designed to establish engineering as a fulfilling career option that requires strong math skills.

Overview of Math Options Summer Camp

The Math Options Summer Camp (MOSC) was developed as an extension of a one-day signature Math Options Career Day held annually for the past thirteen years at PSB. The Math Options Summer Camp was designed to provide more in-depth investigation of STEM careers for girls at the high school level (entering ninth or tenth grades). The weeklong camp has a number of benefits over a one-day event in that more time can be dedicated to the workshops and labs, and projects can be carried over from one day to the next. The format also allows daily interaction with college-aged student mentors and substantial amounts of time spent with PSB faculty and staff. Recreational time allows the girls to strengthen newly formed friendships.

The engineering and technology component of the camp was developed with a number of goals in mind. It was designed around the re-engineering of an existing product (a pair of blue jeans) to create a brand new product (a blue jean bag) that was relevant to the girls and could be completed in 14 hours. The project had to be multidisciplinary and involve hands-on activities in different areas of engineering and technology that matched the girls' abilities and skill set. The project needed to demonstrate how engineering affects people's everyday lives and positively impacts society. Because bags are a common accessory used by young girls, the jean bag was something the girls could easily relate to, thereby making the introduction of the fun aspects of engineering relatively easy. The use of an existing pair of jeans to design a new product introduced the concept of recycling. Requiring the girls to make a product that would be later used for a donation helped accomplish these goals. In order to provide individualized attention and ensure lab safety, the camp was limited to 15 participants. One important goal was to provide positive role models of achievement; thus, the majority of the labs were instructed by female faculty members. College students in STEM majors were hired as mentors. These students received special training on gender issues and how to successfully interact with girls this age. The camp was funded through the Pennsylvania Educational Improvement Tax Credit Program (EITC). This allowed a low registration fee of $125 and the availability of full and half scholarships to girls that demonstrated a financial need. Transportation stipends were also provided to families in need. The camp provided the girls with an opportunity to experience multiple engineering processes and the technology used to design and manufacture a product from beginning to end.

The theme of the engineering portion of the camp was called "Re-enJEANeering" due to the nature of the product being designed. Over the course of the week the girls designed and manufactured jean bags. Since creativity was an important aspect of this camp, the girls were not constrained to making a particular kind of bag. Instead they were allowed to make a bag of any style. A purse, a scrapbooking tote bag, or a BBQ tool holder, are a few such examples.

The camp started with a team building and leadership workshop, and then the students were given an introduction to the product and how it relates to engineering. This was followed by development and construction of their design ideas in the various engineering labs. Finally an applicable business model lesson was given. Throughout the week there was laughter, learning, and personal development by all those involved in the camp. The student mentors and faculty enjoyed the camp as much as the girls. The following sections describe each segment of the camp in detail.

Teamwork Workshop

The opening workshop was designed to help the girls get to know each other and to teach them about successful team work. Other learning objectives included an examination of the factors that relate to team performance, such as an individual's previous experience, cognitive variables such as memory, problem solving and spatial skills, and emotion regulation in the face of stress. The challenge is based on the Jungle Escape Game (teambuilding training game) developed by HRDQ, Inc.

The campers were asked to imagine that they were stranded in the jungle after a plane crash. They had to assemble parts (K'NEX®) to create a helicopter to fly them out of the jungle before monsoon rains started. Campers were assigned to three teams of four to five students. One member of the team was assigned to be the scientific observer and record information about the team's activities and performance. Assembly was limited to 40 minutes, and after 20 minutes the first observer chose a successor. The observer could not speak or help build the helicopter. Students were given a black and white photo of the helicopter and one at a time could look at a model behind a screen. They could not bring pieces with them or touch the model; they had to rely on their memories. When the helicopter was complete, a facilitator checked it for completeness.

In this activity, it is typical for some teams to work well together and finish early while other teams take longer or do not finish in the allotted time. When finished, the team members answered questions through which they analyzed the strengths and weaknesses of their performance. They discussed emotional regulation and the positive and negative emotions that result from working on a challenging problem. One important topic was how leaders both, emerge in teams and harness the strengths of the team members. Various diversity issues were discussed. For example, is it fair to have to use K'NEX® building toys which some campers have never used and tend to be played with more by boys? At the end of the activity, the students were placed into Red and Blue Teams and introduced to their college student mentors and many of the faculty that they worked with throughout the week.

Introduction to the Jean Bag Project

This second workshop began with a discussion of what the engineering profession is all about. It was important for the participants to understand what an engineer is and the significant impact she/he can have on society. The workshop emphasized the fact that products used by the participants in their day-to-day life cannot be manufactured without the involvement of an engineer. A clear understanding of how different fields of engineering contribute to society on many different levels was provided.

Once the attendees had a better understanding about engineering, the design project was introduced. This entailed a discussion of how engineering faculty came up with the idea of Re-enJEANeering and the process that would be followed. It also included demonstrations and examples of both failed and good prototypes, emphasizing that the finished product very rarely looks like the initial idea. The girls learned the importance of being flexible and open to various ideas that are not necessarily their own to ensure an end product of optimum quality.

Constraints and requirements for the product were established, giving campers an opportunity to be creative and still experience a part of practical bounds. The bag was to have at least one handle, at least one ring to connect the handle to the bag (Figure 1), fasteners such as rivets, snaps, Velcro, magnets, or grommets, and one sewn seam. The handles, rings, and fasteners were to support the weight they were designing for, plus 30% of that weight. The students were also asked to complete two bags—one for themselves and one to donate to a community agency called SafeNet that serves women and children.

Figure 1. Examples of ring styles that were available for use.

Before the campers began the design process, they were shown the NIGHTLINE television broadcast video “Deep Dive” (ABC News Productions, 1999) featuring a company called IDEO, located in Palo Alto, California, illustrating a user-centered process for designing products. This company uses a unique approach to brainstorming called the “Deep Dive.” Their approach focuses on having a multidisciplinary team of employees (e.g., anthropologists, psychologists, business professionals, and engineers) totally immerse themselves in the design problem. In this video, the team follows a full design process to redesign a grocery shopping cart. In just five days the multidisciplinary team brainstorms ideas, conducts research, develops multiple prototypes and gathers user feedback.

This video does a very good job of showing how individuals from different backgrounds with different levels of training can work together to develop a usable product. The teamwork represented in the video is something that was incorporated in the Math Options Summer Camp. It also provided insight into what was expected of the campers during the design process.

Ergonomic Bags Workshop

The goal of this activity was to familiarize the campers with the general concept of human factors and how to design an ergonomically correct bag. The first step was to review human factors and ergonomics. The goal of human factors engineering is to improve interactions between humans and systems; specifically it is focused on improving performance, safety, and user satisfaction. The field of ergonomics addresses the relationship between the human body and the environment (Karwowski, 2006).

A backpack was used as an example of ergonomics. Different backpack sizes are recommended based on the user’s size and weight, and the campers were provided with information based on different clinical studies. The American Chiropractic Association (ACA) and the American Academy of Orthopedic Surgeons (AAOS) have provided guidelines for backpack weights, sizes, and usage for children. Experts recommend that the backpack be no more than 10-15% of the child's weight, and it should never exceed more than 20% of a child's weight (O'Neill-Grace, 1999).

In a group activity, campers weighed themselves and then calculated the ideal weight for their backpack (10%-15% of body weight) and the maximum weight (20% of body weight) for their backpack. A discussion session followed to review the impact of backpacks that are too heavy. The attendees came up with examples of what could happen to their bodies if they were carrying a backpack that was too heavy (e.g., headaches, shoulder discomfort, neck pain, and issues with posture). They also discussed the importance of the position of the backpack. At the end of the activity, campers better understood the characteristics of an ergonomically correct backpack. The campers then reviewed ways to make an existing backpack ergonomically correct (e.g., placing heavy things in the bottom of the backpack to help distribute the weight more equally), and they discussed methods of carrying their backpacks correctly.

All of the camp activities needed to be relevant to the jean bags project; therefore, the next step was to apply backpack design recommendations to other bags, including purses. The attendees came up with ways to apply the ergonomically correct design concepts from the backpack to bags. They discussed choices in strap size and strap length, depending on the size of the bag. For example, bags designed to carry less weight can have narrow, long straps in contrast to bags designed to carry more weight, which need wider, shorter straps so that the straps do not dig into the user's shoulder. The session ended with the attendees discussing how they could incorporate these ideas in their bag designs.

Mechanical Engineering Workshop

On the morning of the second day, campers went to several of the mechanical engineering labs. The goal was to give the girls an opportunity to understand the fundamentals behind mechanical engineering and also give them a sense of mechanical engineering as a career option and its relation to everyday products. The project design required the bag to have at least one ring to attach the handle to the bag. In this segment, the attendees modeled rings for their final product using computer-aided-drafting (CAD) and analysis tools used by professional mechanical engineers. They also worked with test machines in the mechanical engineering laboratories.

The session began with a discussion of different options available for temporary and permanent fasteners. These options included rivets, screws, nuts, stitching, glue, and so on. The discussion moved on to the availability of rings in different shapes, sizes, and materials, as shown in Figure 1. The students modeled rings in two different shapes: a round ring and a D-ring using a CAD tool called Pro/ENGINEER®. The stress plots for several of the rings were completed using a finite element analysis package called ANSYS®. Computer simulations were followed by hands-on activities. This included a visit to the materials-testing laboratory on campus.

Campers were split into two groups and each group completed two activities. In one activity, campers were given test samples of rings both of different sizes and made with different materials, such as brass, plastic, and steel. A 10kN capacity Tinius-Olsen Benchtop Universal Test machine was used to see how much weight each ring could support before it failed. Campers performed these tests and drew conclusions regarding the various test samples. The smaller metal rings tended to break, plastic rings elongated before they broke, and the jean fabric ripped before the larger metal ring broke. This exercise helped determine the appropriate material and size for the rings that would support the maximum amount of weight for each camper's bag. In the second activity, campers moved to the manufacturing processes laboratory and learned to cut holes through multiple layers of jean fabric using a drill press as a punch, a crafter's punch, and an awl. They also learned how to use an Arbor Press to set rivets and grommets.

During the week, impromptu testing was completed as necessary. For instance, students could decide to use materials not normally recommended to be used as handles for their bags. Faculty helped the students determine whether their idea was feasible or not.

Cutting Steel and Plastic Engineering Workshop

The plastics engineering workshop was held on the third day of camp in the general manufacturing and plastics laboratories. Campers spent time observing and participating in various part production methods with the intention of gaining an understanding of how things are made. This information was then related to the jean bag project.

In the design choices for the bags, campers had several options for plastic or metal fasteners and components. In the general manufacturing laboratory, campers were exposed to multi-axis computer-numerical-controlled (CNC) machining centers, and they were given an explanation of the different types of metals. Manufacturing methods were described and demonstrated, and the girls were able to participate in some aspect of the manufacturing method and/or the application of the fasteners. This allowed them hands-on time in the fabrication laboratory where they were able to try milling, drilling, hand threading, and riveting, as well as spot, tig, and mig welding.

These activities were followed by a visit to the plastics laboratory where they were introduced to the processes by which raw plastic materials are converted into plastic parts. Each attendee was given a primer on materials and processes after which they advanced to mixing their own colored material; they used injection molding to create their own personalized part (in this case a Frisbee-style disc). They also operated a thermoformer and produced Penn State Nitanny Lion head-shaped forms. At the end of this session, the students had a better understanding of metals and plastics and how parts are manufactured.

Flower Power: Electrical Engineering Workshop

In order to incorporate the electrical engineering component during the design phase of the product, camp participants were brought to the electrical engineering laboratories where they put together a simple circuit using some basic electrical components. At the end of this workshop, participants learned how to solder, which is an important skill for professional electrical engineers. The girls built a device that was a source of light, was battery operated, and was small enough to put in their jean bag. The motivation was to be able to use this handy device to find keys and other small items that tend to get lost inside purses.

The name of the workshop was "Flower Power," because the printed circuit board (PCB) was shaped as a flower. The petals of the flower represented the area where electrical components (potentiometers) are soldered. The potentiometers are variable resistors that look like circular dials. At the center of the PCB a multicolored light emitting diode (LED) was soldered. The LED provided a source of light that could be turned on using a 9-V battery. The potentiometers were used to change the color of the light emitted by the LED.

Due to time constraints, the circuit was predesigned. Kits were put together with the printed circuit board and the various components to build the circuit. Campers were provided with soldering irons, soldering wire, safety glasses, and wire clippers. A Hershey's Kiss was included as part of the kit so that the attendees could easily visualize what a solder joint should look like. After a brief demonstration at the beginning of the workshop, participants soldered their components on to the PCB (see Figure 2) and created a product that could be used with their jean bags to increase its usefulness.

Figure 2. A camper soldering wires to her printed circuit board (PCB) in the Flower Power workshop.

Optimizing Profits Workshop

PSB offers an Interdisciplinary Business with Engineering Studies Major (IBE), which motivated the authors to introduce a "business" component to the camp. The discussion during this workshop focused on how the re-enJEANeered bags could be produced for profit. The camp's participants were asked to come up with different business models. For instance, campers discussed the ideas of selling the bags at craft shows, birthday parties, retail stores, a shop or kiosk, and selling them online.

Attendees were divided into different groups based on the business models they suggested. The girls were given time to brainstorm and come up with the materials required to start their businesses. The girls tended to think beyond basic requirements like tables and a cash register; and considered issues like how they would store and transport their supplies and products.

Campers then performed a cost analysis to decide if a profit could be made based on the current design. Based on the experience of the first four days of camp, they calculated the costs associated with making the bag. A list of all the materials that they had access to throughout the week was provided to them. This list included actual purchase prices and estimated costs for items that were donated. Campers were also required to take into account materials that are not clearly visible, for instance, thread to sew on a button, or hot glue to add embellishments. Costs ranged from under a dollar to around $10.00.

After the cost of raw materials was established, there was a discussion regarding other costs to starting a business, such as rent and labor. Groups decided which business model would be the most successful. This led to a lively discussion on how their businesses could be made profitable. Campers discussed options such as selling their bags at a high price, cutting costs by utilizing space at home, selling online, simplifying the design to cut costs, and purchasing supplies on sale or on clearance. This activity concluded the design cycle of the product.

Wrap Up and Parent Reception

As discussed in the introduction, research shows that one of the reasons why girls do not pursue a degree in engineering is that they do not understand how engineering can make a difference to society. In order to emphasize that engineers help people every day, the girls designed and built two jean bags, as shown in Figure 3. One bag was for the camper to keep and the other was donated to SafeNet, a domestic violence organization in Erie, Pennsylvania. Campers learned how some women and young girls need to escape from a violent situation and leave everything behind. The second bag was filled with items to make life easier for women and children in unfortunate situations. The girls did a great job decorating the bags and often added inspirational messages. At the final presentation to the parents and donors, the participants presented the bags to a representative from SafeNet.

Figure 3. Examples of finished purses.

An overview of engineering careers was also provided to the girls, including aerospace, chemical, civil, computer, electrical, industrial, mechanical, materials, plastics, petroleum, and software engineering fields. In order to provide a good understanding of each of these fields, campers discussed how each of the engineering fields was involved in the design and development of an aircraft. Information was provided regarding engineering majors offered on Behrend's campus, which include computer, electrical, mechanical, plastics, software engineering, and interdisciplinary business with engineering studies and how the week's activities were related to these majors. They were provided with links to the *Sloan Career Cornerstone Center* and *Engineer Your Life,* which provide information about engineering careers, what engineers do, and what steps the girls need to take in high school to pursue one of these majors.

Program Assessment

Based on the goals of the program an assessment strategy was developed in which campers' attitudes about the STEM disciplines were measured before and after the camp using a computerized survey. Each workshop was individually evaluated using closed- and open-ended questions. The first analysis compared the results from the 2008 and 2009 camp sessions. The results of independent sample t-tests found no significant differences ($ps > .05$). Therefore, in the following analyses, the data for the two years are analyzed together with 28 campers, 2008 ($N = 13$) 2009 ($N = 15$). The data reported here are from the morning sessions that represent the engineering part of the camp and revolved around the Jean Bag Project.

Pre-camp and post-camp surveys. When the students first arrived they were directed to a Web site specifically designed for the program. Students completed a brief questionnaire where they rated a series of statements on a scale of 1 = strongly disagree to 5 = strongly agree. At the end of the program students answered the same questions. Table 2 shows the means (*M*) and standard deviations (*SD*) of the pre-camp and post-camp responses. Overall, students were very positive about the STEM fields coming into the program, so it is not surprising that they remained positive at the end. The majority of questions show mean post-camp scores somewhat more positive than pre-camp scores, but paired sample t-tests did not reach statistical significance (*ps* > .05).

Workshop evaluations. After each workshop, the students completed a brief four- question assessment. Open-ended questions asked campers what they liked the most and the least. For the ratings, participants used a scale of 1 = strongly disagree to 5 = strongly agree, as to whether the workshop wasinteresting and enjoyable and increased their understanding of the topic. Paired samples t-tests were conducted to compare the 2008 and 2009 groups, and the results showed no differences, therefore the data reported in Table 3 included all participants. The results showed that the workshops were rated highly, with the majority of responses (93%) either agreeing or strongly agreeing that the workshops were both interesting and enjoyable and that they increased their understanding of the topic. The workshops that were considered most interesting and enjoyable were the Flower Power and Cutting Steel workshops. The least highly rated was the Optimizing Profits workshop. The campers' comments suggested that they were less positive about Optimizing Profits because it was less hands-on/laboratory-based than the other workshops.

Overall assessment. The post-camp survey also included seven statements that were designed to assess campers' overall feelings about the Jean Bag project and about Math Options Summer Camp in general. They were also asked about the college student mentors. The results showed that the Jean Bag project was both fun (*M* = 4.59, *SD* = .694) and educational (*M* = 4.04, *SD* =.81). Students reported nearly unanimous agreement with the statement that they would recommend the camp to other students (*M* = 4.78, *SD* = .577). The highest ratings were for the interaction with the college student mentors. Campers felt strongly that they were good role models (*M* = 4.81, *SD* = .396) and enjoyed working with them (*M* = 4.89, *SD* = .32). Most campers wanted to stay in touch with each other after the camp (M = 4.56, SD = .698).

Conclusions

The Math Options Summer Camp program has now been implemented for two years and overall it has been successful. The results of the evaluations show that the campers were very positive about the experience and left the camp knowing much more about specific STEM disciplines. Attitudes about the STEM fields were strong coming into the camp and, therefore, did not significantly improve, but this suggests that educators should reach out to a broader segment of the population. Recruitment is one area that could be improved. The authors intended to target less affluent and more diverse participants and offered scholarships to help support the costs, but were only partially successful. Many high school students from less affluent backgrounds need to work during the summer months or care for younger children, and they often do not have transportation to campus.

Although developing and implementing the program was extremely time consuming, the

Table 2. Means and Standard Deviations (SD) of Ratings on the Pre-camp and Post-camp Surveys. Paired sample t-tests and p values are also shown.

Pre-Camp Mean	Pre-Camp SD	Post-Camp Mean	Post-Camp SD	t	p	Statement
3.85	1.29	3.77	1.33	.57	.57	I like math.
4.07	0. 96	4.26	0.81	1.55	.13	I like science.
4.30	1.10	4.59	0.69	1.49	.15	I am considering a career in a math or science field.
4.33	0.92	4.48	0.80	1.65	.11	In high school I will take math or science courses even if they are not required.
4.37	0.74	4.59	.57	1.65	.11	It is important for everyone to have a basic understanding of Science, Technology, Engineering, Math (STEM).
3.44	1.19	3.74	1.26	1.35	.19	Women are not encouraged as much as men to go into STEM fields.

experience has been valuable for establishing and strengthening interdisciplinary relationships among faculty and staff. In working together on these integrated projects, everyone learned more about the others' discipline and how they often overlap and complement each other. The college student mentors also reported a very positive experience; not only did they learn more about the wide variety of STEM fields, but they also realized how rewarding it is to work with young people.

The logistics of implementing intensive STEM education outreach programs can be daunting. At PSB, the Continuing Education Office orchestrated the administrative details, such as obtaining funding, recruiting and registering the campers, and providing key staff support. The Psychology building, centrally located on campus, was used as the "clubhouse" for the program. Starting and ending each day in one place gave the campers a sense of familiarity and identity. For the academic institution, just beneath the more altruistic reasons for outreach activities lies the secondary hope that they will aid in recruiting good students. Although the primary goal was to increase knowledge and interest in STEM careers, the camp also brought young girls to this campus and most (80%) reported planning to apply to PSB for college.

At the end of the camp, students were asked to describe in their own words how this experience influenced their attitudes about careers in STEM. For those already interested in STEM careers, the camp illustrated the wide variety of fields within a discipline. For example, one camper said, "I knew I liked engineering when I came here, but I didn't know all of the different types and what they consisted of."

For undecided students, the camp provided a mind-opening experience, "I think it encouraged me to keep my mind open for different careers and career choices." For others the camp challenged some of their stereotypes. One girl wrote, "I learned that engineering is not working in an office. There is so much field work that is a lot of fun… Also engineering really helps people. We couldn't survive without all the things made by engineers." Students also began to think about gender roles and their limitations. One student commented, "It helped me learn more about careers that are mostly considered men's work, I am now considering other careers that I would not have originally thought of."

When the campers were asked how they would improve the camp the most common response was to make it longer and to let the campers stay in the dorms overnight. Students were overwhelmingly positive; one camper summed it up well, "Math options was a blast this year!! Thanks for letting me have the opportunity to come here and learn and have fun. It was awesome!"

Table 3. Results of Workshop Evaluations. Means (M) and Standard Deviations (SD) for Ratings of Enjoyment (Enjoy) and Understanding (Understand). Representative Comments for "Liked the Most" and "Liked the Least" Questions

Workshop		Enjoy	Understand	Liked the most	Liked the least
Teamwork	M	4.57	4.54	building the helicopter	observing instead of building
	SD	0.63	0.64	fun to work with my team	time limits
Ergonomics	M	4.29	4.37	weighing the bags	PowerPoint
	SD	0.76	0.69	how much you should carry	sitting too long
CAD/	M	4.30	4.15	working on computers	confusing
Analysis	SD	0.78	0.91	using engineering technology	messing up the model
Breaking	M	4.63	4.42	using the machines	like to test more things
Stuff	SD	0.56	0.76	breaking stuff!	confusing instructions
Flower	M	4.81	4.52	making the light	confused about the wiring
Power	SD	0.48	1.05	using the soldering iron	700 degrees hot
Cutting	M	4.86	4.61	welding is awesome	noisy
Steel	SD	0.36	0.74	the cool masks	waiting round
Plastic is	M	4.61	4.57	getting the bottles	waiting for machines
Fantastic	SD	0.83	0.74	seeing the stuff made	standing around
Optimizing	M	3.78	3.89	finding the cost	a little confusing
Profits	SD	1.12	1.01	how to make money	listening

Dr. Vibhuti Dave is an assistant professor in the Electrical, Computer, and Software Engineering program at Penn State Erie, The Behrend College, Erie.

Dr. Dawn Blasko is an Associate Professor of Experimental Psychology at Penn State Erie, The Behrend College, Erie.

Ms. Kathryn Holliday-Darr is a Senior Lecturer in Engineering Graphics in the School of Engineering at Penn State Erie, the Behrend College, Erie.

Dr. Jennifer Trich Kremer is a Web Experience Architect at WellPoint Inc, North Haven, Connecticut.

Mr. Robert Edwards is a lecturer in engineering at Penn State Erie, The Behrend College, Erie.

Ms. Melanie Ford is a Lecturer in the School of Engineering at Penn State Erie, The Behrend College, Erie.

Ms. Lucy Lenhardt is a faculty member at Penn State Erie, the Behrend College, Erie, in the Plastics Engineering Technology Department and general manager of their Plastics Research and Instructional Lab.

Ms. Barbara Hido is the Director of the Penn State Educational Partnership Program (PEPP) at Penn State Erie, The Behrend College, Erie.

References

ABC News. (Producer) (1999). *The deep dive* [DVD]. Available from http://abcnewsstore.go.com/.

American Chiropractic Association [ACA]. (n.d.). *American Chiropractic Association offers backpack safety checklist.* Retrieved June 2008 from http://www.acatoday.org/pdf/backpack_checklist.pdf.

American Academy of Orthopedic Surgeons [AAOS]. (2003). *Orthopedic surgeons stress using common sense when it comes to overloading backpacks.* Retrieved June 2008 from http://www6.aaos.org/news/pemr/releases/release_archive.cfm?releasenum=192.

Bee, D., Puck, B., & Heimdahl, P. (2007). Ten years of STEPS success: significant impact in attracting girls to science, technology and engineering careers. *Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition.* Honolulu, Hawaii. Retrieved February 2010 from http://soa.asee.org/paper/conference/paper-view.cfm?id=6112.

Burket, S., Small, C., Rossetti, C., Hill, B., & Gattis, C. (2008). A day camp for middle school girls to create a STEM pipeline. *Proceedings of the 2008 American Society for Engineering Education Annual Conference & Exposition.* Pittsburgh, PA. Retrieved February 2010 from http://soa.asee.org/paper/conference/paper-view.cfm?id=8515.

Fry, C., Davis, J., & Shirazi-Fard, Y. (2008). Recruitment and retention of females in the STEM disciplines: The annual girl scout day camp at Baylor University. *Proceedings of the ASEE/IEEE Frontiers in Education. Conference* Saratoga Springs, NY. Retrieved February 2010 from http://www.fie-conference.org/fie2008/papers/1694.pdf.

Haemmerlie, F. M., & Montgomery, R. L. (1991). Goldberg revisited: Pro-Female Evaluation Bias and Changed Attitudes Towards Women by Engineering Students, *Journal of Social Behavior and Personality, 6*(2), 179-194.

Hersh, M. (2000). The changing position of women in engineering worldwide. *IEEE Transactions on Engineering Management. 47*(3), 345-359.

Hughes, W. J. (2002). Gender attributions of science and academic attributes: an examination of undergraduate science, mathematics, and technology majors. *Journal of Women and Minorities in Science and Engineering, 8*(1), 53-65.

Jungle Escape Game [Apparatus]. (2009). King of Prussia Pennsylvania: HRDQ. Retrieved May 2000 from http://www.hrdqstore.com/Jungle-Escape-Game-.html.

Karlin, J. (2005). An interactive event model to introduce young women to engineering: evolution of a scalable program and lessons learned. *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition.* Portland, Oregon. Retrieved February 2010 from http://soa.asee.org/paper/conference/paper-view.cfm?id=21212.

Karwowski, W. (2006). The discipline of ergonomics and human factors. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (3rd ed.). (pp. 1-31). Hoboken, New Jersey: Wiley.

K'NEX Brands L. P. [Apparatus] (2010) Pennsylvania: the Rodon Group. Retrieved May 2000 from http://www.knex.com.

National Science Board. (2008). *Science and Engineering Indicators 2008*. Arlington, VA: National Science Foundation.

National Science Foundation: Division of Science Resource Statistics [NSF]. (2008). S*cience and engineering degrees: 1996-2006* (Detailed Statistical Tables NSF 08-321). Retrieved February 2010 from http://www.nsf.gov/statistics/nsf08321.

O'Neill-Grace, C. (1999, Sept). How & why: Backpack tips for kids. *Washington Post.* pp. Z17.

Plant, A. E., Baylor, A. L., Doerr, C. E., & Rosenberg-Kima, R. B. (2009). Changing middle-school students' attitudes and performance regarding engineering with computer-based social models. *Computers and Education. 53*, 209-215. Plotkowski, P., Sheline, M.A., Dill, M., & Noble, J. (2008). Empowering girls: measuring the impact of science technology and engineering preview summer camps (STEPS). *Proceedings of the 2008 American Society for Engineering Education Annual Conference & Exposition.* Pittsburgh, PA. Retrieved February 2010 from http://soa.asee.org/paper/conference/paper-view.cfm?id=7594.

U.S. Department of Education Institute of Education Sciences, National Center for Education Statistics (2008). *Projections of Education Statistics to 2017.* NCES 2008-078, 2008

Weston, V., Bonhivert, A., Elia, A., Hsu-Kim, H., & Ybarra, G. (2008). Work in progress: A stem educational outreach day for young females. *Proceedings of the 2008 Frontiers in Education Conference.* Saratoga Springs, NY. Retrieved February 2010 from http://fie-conference.org/fie2008/papers/1626.pdf.

Trajectories of Mathematics and Technology Education Pointing To Engineering Design

Jenny L. Daugherty, George C. Reese, and Chris Merrill

Abstract

A brief examination and comparison of mathematics and technology education provides the background for a discussion of integration. In particular, members of each field have responded to the increasing pressures to better prepare students for the technologically rich, globally competitive future. Approaches based within each discipline are varied across curriculum and instructional strategies. However, when examining the disciplines' historical paths, there are important similarities to consider in determining how best to affect student learning in both mathematics and technology education. The authors contend that engineering design is the appropriate contextual area for integrating mathematics in technology education.

Trajectories of Mathematics and Technology Education Pointing To Engineering Design

The national learning standards associated with mathematics and technology education indicate a relationship between the disciplines of mathematics and technology education. Mathematics is referred to 30 times in the *Standards for Technological Literacy: Content for the Study of Technology* (International Technology Education Association (ITEA), 2000/2002) and technology is used over 20 times in the National Council of Teachers of Mathematics' *Principles and Standards for School Mathematics* (2000). For example, standard three in the *Standards for Technological Literacy* states that "students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study" (ITEA, 200/2002, p. 44). The *Connections* standard in the *Principles and Standards for School Mathematics* states that students will recognize and apply mathematics in contexts outside of mathematics, and the *Problem Solving* standard reads that students will solve problems that arise in mathematics and in other contexts.

Both disciplines clearly include one another, at least in general terms. Their incorporation or relationship with each other appears to center on use. For example, upon review of these standards documents alone, the scope or purpose of technology in mathematics would appear to be that of instructional technology. Mathematics educators are primarily concerned with using technology to aid in instruction (e.g., computers, calculators, software) and facilitate student learning. Technology educators, on the other hand, are focused on how to use mathematics to understand, use, and design different technologies. Just as mathematics educators appear to see technology as a tool in service to solving mathematical problems, technology educators appear to see mathematics as a tool in service to solving technological problems (Merrill, Reese, & Daugherty, 2010).

However, does a closer relationship exist between the two disciplines beside the one-dimensional emphasis on use found in the standards? If a closer relationship were to exist, what might integrate the two disciplines? These two questions are the primary focus of this article. Moving beyond a simple analysis of standards documents, the historical trajectories of mathematics and technology education, as they relate to each other, are explored. By exploring these histories, a future point of integration through engineering design is explored.

Mathematics Education and Technology

Many reports have called for better preparation in mathematics and science, and for increased skills for the technology-rich workplace of the 21st century (American Association of University Women, 2000; Borgman et al., 2008; National Commission on Mathematics and Science Teaching for the 21st Century, 2000; National Mathematics Advisory Panel, 2008). Yet, many parents and teachers consider mathematics as a very traditional process of technology-independent practice, focused on algorithms, facts, procedures, and so forth. The history of technology integration into mathematics is embedded in the developments and debates about mathematics education in more general terms.

The "new mathematics movement" and the National Council of Teachers of Mathematics' (NCTM) standards-based reform are two movements that occurred within mathematics, with an era of "back to basics" in between (Herrera & Owens, 2001). The new mathematics movement developed in the 1960s in response to the launch of Sputnik and concerns over the nation's mathematical skills. The College Entrance Examination Board appointed a Commission on Mathematics, which developed a nine-point program that "called for preparation in concepts and skills to prepare for calculus and analytic geometry at college entry" (Herrera & Owens, 2001, p. 85), and it included sets, logic, algebraic structures, and pedagogical approaches of discovery.

The second movement focused on the NCTM Standards, which were released in 1989. The National Science Foundation (NSF) funded several curriculum development projects. These curricula emphasized conceptual learning, and many had a modular, thematic approach that integrated the content strands. For example, in a module of the Interactive Mathematics Program (Fendel, Resek, Alper, & Fraser, 2004) called the "Game of Pig," students work on probability, averaging, recognizing patterns, and making predictions through learning the rules of a simple dice game. In "Frogs, Fleas, and Painted Cubes," (Lappan, Fey, Fitzgerald, Friel, & Phillips, 1998) students explore quadratic relationships through area and perimeter problems. In general, the standards-based curricula had more hands-on activities and fewer drill and practice exercises. They also appeared at a time when instructional technology in mathematics was becoming more prevalent due to its increased power and decreased cost. Java applets, dynamic geometry software, and computer algebra systems are just a few tools that began to appear more frequently in classrooms in the 1990s.

In terms of technology, the mathematics standards made explicit that technology should be used in teaching, stating that, "appropriate calculators should be available to all students at all times," (National Council of Teachers of Mathematics, 1989, p. 8); this would enable students to focus on the problem-solving aspect, not simple computations. Recommendations at the high school level also called for the use of technology. The integration of ideas from algebra and geometry is particularly strong, with graphical representation playing an important connecting role. The standards also called for increased use of "computer-based explorations of 2-D and 3-D figures" and "real-world applications and modeling" (p. 126) as well as decreased attention to "paper-and-pencil graphing of equations by point plotting" and "paper-and-pencil solutions to trigonometric equations" (p. 127). Instructional technologies for the mathematics classroom were being developed and refined. The most dominant is the graphing calculator. Today, Texas Instruments sells over a hundred thousand calculators annually in the state of Illinois alone (personal communication, 2009). Software for performing mathematics calculations via computers has also been developed. Examples include dynamic geometry (Scher, 2000), computer-based algebra (Texas Instruments, 1997), and data analysis (Finzer, 2005).

In 2000, NCTM revised its standards, seeking to simplify and clarify their vision with the *Principles and Standards for School Mathematics (PSSM)*. The *PSSM* are the basis for most of the discussion and curriculum development in the mathematics education community today. The *PSSM* contain six principles (Equity, Curriculum, Teaching, Learning, Assessment, and Technology), five content standards (Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability) and five process standards (Problem Solving, Reasoning and Proof, Communication, Connections, and Representation). The standards are broken down by grade level and are expanded upon in the Navigations Series (e.g., Pugalee et al., 2002) and with online resources and articles in NCTM journals.

Today, the revised curricula that are based on the *PSSM* contain frequent technology applications. For example, the high school curricula College Preparatory Mathematics (Sallee & Hoey, 2002) and Core-Plus (Coxford et al., 1998) both have graphing calculators as important components of typical lessons. Programs such as the "Cognitive Tutor" (Hadley, 1998-2001) make extensive use of the computer. Even at the university level there are technology-rich options for learning mathematics. The Calculus & Mathematica course (Uhl, 2002), for example, has all lectures and homework assignments in the form of Mathematica notebooks. However, there is still very little data about how widely the reform curricula have been adopted and which curricula are most effective (National Research Council, 2004).

The *PSSM* will almost certainly continue to be the focal point for discussion and development in mathematics education, and technology is a crucial component of the *PSSM*. The "Vision for School Mathematics" described in the standards is still one in which "technology is an essential part of the environment" (National Council of Teachers of Mathematics, 2000, p. 3). Many of the exemplary lessons in the Navigations series include uses of spreadsheets, graphing calculators, and dynamic geometry programs. The *PSSM* are bolstered by online activities that include Java applets and other technologies. Graphing calculators are permitted on the SAT, ACT, and Advanced Placement mathematics examinations.

The role of technology in mathematics curricula and in mathematics teaching and learning has also been uncertain and contentious. A study by Wenglinsky (1998) looked at National Assessment of Educational Progress data and found that using computers, especially for drill and practice, had a negative correlation with student achievement in mathematics at the fourth and eighth grades. Yet, 10 years later, the report of the National Mathematics Advisory Panel included a statement that the use of technology is promising when "Computer-assisted instruction supports drill and practice" (Faulkner, 2008). And, of course, clarity is hindered by the reality that digital technologies are a moving target for impact studies. As growing numbers of students use cell phones, computers, MP3 players, and sophisticated video games, computer literacy might be assumed by mathematics teachers. Yet, many teachers remain unsure if technology is a ladder or a crutch for students (Brown et al., 2007), and best practices must evolve as the tools change.

Integration through Engineering Design

Through an examination of mathematics and technology education, several similarities are apparent, including that both disciplines have (a) developed learning standards, (b) make use of instructional technologies, (c) call for further study to discover more effective curricular and instructional approaches, (d) suggest contention within the ranks as to the purpose of the subjects, (e) see no reason to change from prior practices for some teachers and schools, (f) call for an applied/integrative/authentic approach, and (g) evolve, based on the needs of society (Merrill, Reese, & Daugherty, 2010). In addition to these similarities, there appears to be room for members of both disciplines to collaborate on developing effective practices centered on problem solving. The *PSSM* emphasizes the development of students' problem-solving skills in both abstract and applied contexts, as does the *Standards for Technological Literacy* (STL).

With the increasing national attention on science, technology, engineering, and mathematics (STEM) education (e.g., *Rising Above the Gathering Storm: Energizing and Employing American for a Brighter Future,* 2006), many have recognized the potential benefits of even stronger integrations across these disciplines. Perhaps the key point of future integration is engineering design, as a specific type of problem solving (Jonassen, 2000). Technology education has particularly moved to embrace an engineering-oriented perspective as an avenue to develop meaningful and authentic problem-solving capabilities in students. For example, Warner and Morford (2004) found in their study that 57 technology education programs offered coursework on the study of design. In addition, different initiatives, such as the NSF-funded National Center for Engineering and Technology Education (Hailey, Erekson, Becker, & Thomas, 2005), have been developed to infuse engineering into technology education. Numerous curriculum projects also have been initiated to incorporate various aspects of engineering, including an emphasis on design. A few of these projects include "Project Lead the Way™" (PLTW), "Engineering by Design," and "Engineering the Future: Science, Technology, and the Design Process.™"

The incorporation of engineering design into technology education has primarily emphasized a prescriptive, step-by-step model or a trial-and-error approach (Wicklein & Thompson, 2008). These approaches, however, have been criticized as simplifying the process of design and not being supported by research exploring how engineers design (Mawson, 2003; McCormick, Murphy, & Hennessy, 1994; Welch, 1999; Williams, 2000). The current technology education approach to engineering design often discounts or downplays the significant role of mathematical calculations in formulating designs (Wicklein & Thompson, 2008). As Lewis (2005) argued, a more analytic design approach, where the student relies upon mathematics and scientific principles to make decisions, "poses a challenge" (p. 48) for technology education. This is supported by McAlister's study (2005) of 44 technology teacher education pre-service programs, finding that only 17% of teachers had completed the mathematics requirements to teach "Project Lead the Way" courses.

Although there are many factors involved in engineering design, specifically isolating mathematics as an area that could use more attention within technology education, it could spur a closer integration across the disciplines. Through the examination of the historical trajectories of mathematics and technology education, it appears that the time may be right for a more fully integrated approach, whereby both disciplines approach engineering design drawing from each area's strengths, affecting student learning more fully. For example, Merrill, Custer, Daugherty, Westrick, and Zeng (2008) found in their study that high school students believe that mathematics (and science) concepts are better understood when they are connected to solving a problem or building an artifact.

The National Academy of Engineering Committee on K-12 Engineering Education pointed out that there is a reciprocal relationship between mathematics and engineering, whereby engineers use mathematics (and science) in their work, and mathematicians use the products of engineering in their work (Katehi, Pearson, & Feder, 2009). Engineers use mathematics in a variety of ways from describing to analyzing data, to building and analyzing models. The committee studied the status of K-12 engineering education and came to the conclusion that engineering could be the avenue toward the development of an effective and interconnected STEM education system. Although building a fully integrated STEM education system would require substantial structural changes to schools, the committee argued that engineering would "leverage the natural connections between STEM subjects" (p. 11).

Conclusion

There is a pressing need for relevance in all aspects of the curriculum, but especially in the STEM curriculum. In particular, mathematics education has continually struggled with relevance in terms of students' interests. Mathematics courses at the middle and high school levels often leave students unconvinced that the content is useful to their experience, let alone essential. And technology education has struggled with relevance to the core curriculum in schools and with image. As Merrill et al., (2008) pointed out in their study, "students take technology education courses because they are fun and activity-based, not mathematics or science-based" (p. 61). Integration through engineering design might address these issues of relevance within both disciplines.

John Dewey (1938, 1963) asserted that all education should be grounded in experience. Perhaps it is time to implement his approach with a deep connection between mathematics education and technology education. It is a premise of both disciplines that the ways in which mathematics or technology is taught is an essential component to how well students learn. Key to this notion is the authenticity of the task. That is, how closely do the problem situations in a classroom setting resemble those that are confronted by a mathematician, an engineer, or a mathematically and technologically literate citizen? It is clear that a connection between the two disciplines exists, but further collaboration, authentic learning activities, research-based findings, and above all, communication between the disciplines, needs to continue and flourish. In particular, each discipline should use a more holistic approach to problem solving (Moss, Osborn, & Kaufman, 2003). As Merrill and Comerford (2004) pointed out, "students will begin to see the 'connections or linchpins' that connect different fields of learning" (p. 10) through a more integrated approach.

Both communities would benefit from collaborative activities and research. Both disciplines' trajectories are aligning to make those efforts more feasible and necessary. There are well-established standards in both fields, and new programs have been developed to implement those standards. In addition, mathematics and technology education have had major curricular development efforts during recent years that should further a more intensive integration. A key opportunity for integration is presented in the new Common Core Standards Initiative (2010). The mathematics standards include modeling, both as a unique standard and as a topic integrated throughout the others. Students are expected to estimate, plan, design, model, analyze, and interpret. This effort coalesces with the call for mathematics to be a gateway rather than a gatekeeper (Bryk & Treisman, 2010) and with new curricula, such as the "Gateway to Engineering" (Rogers, Wright, &Yates, 2010) used in middle schools to integrate significant mathematics into the school curriculum through the introduction of engineering concepts.

The most important component is the depth of the connection. In a unified educational experience, the technology is not learned for the sake of the mathematics (as most educational technology in math is today), and the mathematics is not used merely to understand a piece of technology (unless one is inquiring into how it is made), but rather the educational ends should drive the united efforts. There is growing competition for space in the already-packed curricula of high schools. Students may be forced to choose, for example, between a pre-engineering course and an AP mathematics course; such a decision might be made for purposes other than the educational interests of the student, but rather for such concerns as test preparation or college admissions expectations. However, as Reeves (2009) commented, time in school should not be a "zero-sum game," where traditional electives like technology education exist as "extras" in the school curriculum – when time permits.

The school change literature (i.e., Fullan, 2005; Hargreaves & Goodson, 2006) advocates connections, yet they rarely occur. Why is this so difficult, and what could be done to change this? The two areas, mathematics and technology education, represent an evolution – the farthest ends of the STEM education spectrum. Mathematics education has grown from a place of unquestioned importance. Its utility as a tool for other scientific disciplines is undeniable ("the queen of the sciences," Gauss said of mathematics). This power has made mathematics education a test-based filter for academic success, and it has in turn become a contentious domain. Technology education evolved from roots in manual training, industrial arts, and career and technical education – the hands-on training for the non-college-bound student. Bringing these two disciplines together would have unique power and social significance, and engineering design seems a viable avenue for this type of integration.

Dr. Jenny L. Daugherty is an Assistant Professor in the department of Organizational Leadership and Supervision in the College of Technology at Purdue University, Indiana. She is a member of the Gamma Rho Chapter of Epsilon Pi Tau.

Dr. George C. Reese is the Director of the Office of Mathematics, Science, and Technology Education (MSTE) in the College of Education at the University of Illinois, Urbana-Champaign.

Dr. Chris Merrill is a Professor in the Department of Technology in the College of Applied Science and Technology at Illinois State University, Normal. He is a member of the Alpha Chapter of Epsilon Pi Tau.

References

American Association of University Women. (2000). *Tech-savvy: Educating girls in the new computer age* (Executive Summary). Washington, DC: American Association of University Women. Retrieved May 12, 2010, from http://www.aauw.org/research/girls_education/techsavvy.cfm.

Borgman, C. L., Abelson, H. Dirks, L., Johnson, R., Koedinger, K. R., Linn, M. C., Lynch, C. A., Oblinger, D. G., Pea, R. D., Salen, K., Smith, M. S., & Szalay, A. (2008). *Fostering learning in the networked world: The cyberlearning opportunity and challenge, A 21st Century agenda for the National Science Foundation* (Report of the NSF Task Force on Cyberlearning). Washington, D.C.: National Science Foundation.

Brown, E. T., Karp, K., Petrosko, J. M., Jones, J., Beswick, G., Howe, C., & Zwanizig, K. (2007). Crutch or catalyst: Teachers' beliefs and practices regarding calculator use in mathematics instruction. *School Science and Mathematics, 107*(3), 102-116.

Bryk, A. S., & Treisman, P. U. (2010, April 18). Make math a gateway, Not a gatekeeper. [Commentary]. *The Chronicle of Higher Education.* Retrieved July 29, 2010 from http://chronicle.com/article/Make-Math-a-Gateway-Not-a/65056/

Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology. (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future.* Washington, DC: National Academies Press.

Common Core State Standards Initiative. (2010). *Common core standards for mathematics.* Retrieved June 13, 2010, from http://corestandards.org/assets/CCSSI_Math%20Standards.pdf.

Coxford, A. F., Fey, J. T., Hirsch, C. R., Schoen, H. L., Burrill, G., Hart, E. W., Watkins, A.E., Messenger, M. J., & Ristema, B. (1998). *Contemporary mathematics in context: A unified approach, Course 1A, Part A.* New York, NY: Glencoe McGraw-Hill.

Dewey, J. (1938/1963). *Experience and education.* New York, NY: Collier Books.

Faulkner, L. R. (2008). *Foundations for success: National Mathematics Advisory Panel (Final Report Briefing).* Washington, D.C.: U. S. Department of Education. Retrieved January 16, 2009 from http://www.ed.gov/about/bdscomm/list/mathpanel/report/report-presentation.ppt

Finzer, W. (2005). *Fathom:* Dynamic Data Software (Version 2.0): Emeryville, CA: Key Curriculum Press.

Fendel, D., Resek, D., Alper, L., & Fraser, S. (2004). *Interactive mathematics program: Integrated high school mathematics, Year 1.* Emeryville, CA: Key Curriculum Press.

Fullan, M. (2005). The meaning of educational change: A quarter of a century of learning. In A. Lieberman (Ed.). *The roots of educational change: International handbook of educational change* (pp. 202-216). Netherlands: Springer.

Hadley, W. S. (1998-2001). *Cognitive Tutor: Algebra 1.* Pittsburgh, PA: Carnegie Learning, Inc.

Hailey, C. E., Erekson, T., Becker, K., & Thomas, M. (2005). National Center for

Engineering and technology education. *Technology Teacher, 64*(5), 23-26.

Hargreaves, A., & Goodson, I. (2006). Educational change over time? The sustainability and nonsustainability of three decades of secondary school change and continuity. *Educational Administration Quarterly, 42*(1), 3-41.

Herrera, T. A., & Owens, D. T. (2001). The "new new math"? Two reform movements in mathematics education. *Theory into Practice, 40*(2), 84-92.

International Technology Education Association [ITEA}. (2000/2002). *Standards for TechnologicalLiteracy: Content for the Study of Technology.* Reston, VA: Author.

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research & Development, 48*(4), 63-85.

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

Lappan, G., Fey, J. T., Fitzgerald, W. M., Friel, S. N., & Phillips, E. D. (1998). *Frogs, fleas, and painted cubes: Quadratic relationships.* White Plains, NY: Dale Seymour.

Lewis, T. (2005). Coming to terms with engineering design as content. *Journal of Technology Education, 16*(2), 37-54.

Mawson, B. (2003). Beyond 'the design process': An alternative pedagogy for technology education. *International Journal of Design Education, 13*(2), 117-128.

McAlister, B. (2005). *Are technology education teachers prepared to tech engineering design and analytical methods?* Paper presented at the International Technology Education Association Conference, Kansas City, MO.

McCormick, R., Murphy, P., & Hennessy, S. (1994). Problem-solving processes in technology education: A pilot study. *International Journal of Technology and Design Education, 4*(1), 5-34.

Merrill, C., & Comerford, M. (2004). Technology and mathematics standards: An integrated approach. *The Technology Teacher, 64*(2), 8-12.

Merrill, C., Custer, R.L., Daugherty, J., Westrick, M., & Zeng, Y. (2008). Delivering core engineering concepts to secondary level students. *Journal of Technology Education, 20*(1), 48-64.

Merrill, C., Reese, G., & Daugherty, J. (in press). Mathematics education. In P.A. Reed & J.E. LaPorte (Eds.), *Research in technology education.* Council on Technology Teacher Education 59th Yearbook, Woodland Hills, CA: Glencoe McGraw Hill. Moss, D. M., Osborn, T. A., & Kaufman, D. (2003). Going beyond the boundaries. (pp. 1-11). In D. Kaufman, D. M. Moss, & T. A., Osborn (Eds.). *Beyond the boundaries: A trandisciplinary approach to learning and teaching.* Wesport, Conn: Praeger.

National Commission on Mathematics and Science Teaching for the 21st Century. (2000). *Before it's too late: A report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century.* Washington, DC: U.S. Department of Education.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Mathematics Advisory Panel. (2008). Foundations for success: *The final report of the National Mathematics Advisory Panel.* Jessup, MD: U.S. Department of Education.

National Research Council. (2006). *Rising above the gather storm: Energizing and employing America for a brighter economic future.* Committee on Science, Engineering, and Public Policy. Washington, DC: National Academies Press.

National Research Council. (2004). *On evaluating curricular effectiveness: Judging the quality of K-12 mathematics evaluations.* Washington, D.C.: The National Academies Press.

Pugalee, D. K., Frykholm, J., Johnson, A., Slovin, H., Malloy, C., & Preston, R. (2002). *Navigating through geometry in grades 6-8.* Reston, VA: National Council of Teachers of Mathematics.

Reeves, D. B. (2009). *Leading change in your school: How to conquer myths, build commitment, and get results.* Alexandria, VA: Association for Supervision and Curriculum Development.

Rogers, G., Wright, M., & Yates, B. (2010). *Gateway to engineering.* Clifton Park, NY: Delmar CENGAGE Learning.

Sallee, T., & Hoey, B. (2002). *College preparatory mathematics 1: (Algebra 1)*. Sacramento, CA: CPM Education Program.

Scher, D. (2000). Lifting the curtain: The evolution of Geometer's sketchpad. *The Mathematics Educator, 10*(1), 42-48.

Texas Instruments. (1997). Cabri Geometry II. Austin, TX: Texas Instruments.

Uhl, J. (2002). Calculus *& mathematica* [World Wide Web]. Retrieved April 21, 2002, from http://www-cm.math.uiuc.edu/

Warner, S. A., & Morford, L. L. (2004). The status of design in technology teacher education in the United States. *Journal of Technology Education, 15*(2), 33-45.

Welch, M. (1999). Analyzing the tacit strategies of novice designers. *Research in Science & Technological Education, 17*(1), 19-34.

Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics.* Princeton, NJ: Educational Testing Service.

Wicklein, R. C., & Thompson, S. A. (2008). The unique aspects of engineering design. In R. L. Custer & T. L. Erekson (Eds.), *Engineering and technology education* (pp. 57-76). Council on Technology Teacher Education 57th Yearbook, Woodland Hills, CA: Glencoe McGraw Hill.

Williams, P. J. (2000). Design: The only methodology of technology? *Journal of Technology Education, 11*(2), 48-60.

Advancing the "E" in K-12 STEM Education

Ronald Rockland, Diane S. Bloom, John Carpinelli, Levelle Burr-Alexander, Linda S. Hirsch and Howard Kimmel

Abstract

Technological fields, like engineering, are in desperate need of more qualified workers, yet not enough students are pursuing studies in science, technology, engineering, or mathematics (STEM) that would prepare them for technical careers. Unfortunately, many students have no interest in STEM careers, particularly engineering, because they are not exposed to topics in these fields during their K-12 studies. Most K-12 teachers have not been trained to integrate relevant STEM topics into their classroom teaching and curriculum materials. This article explores best practices for bringing engineering into the science and mathematics curriculum of secondary school classrooms by describing a project that utilizes concepts representing the merger of medicine, robotics, and information technology. Specific examples demonstrating the integration into the teaching of physics, biology, and chemistry are provided. Also considered are the critical issues of professional development for classroom teachers, improved preparation of future teachers of STEM, and the development of curriculum materials that address state and national content standards.

Introduction

Not enough students are interested in pursuing careers in science, mathematics, technology and especially engineering, at a time when the United States currently has a shortage of qualified workers in STEM fields (NSB, 2008). One of the more critical reasons most students are not interested in pursuing careers in these fields is that they are not exposed to relevant topics in STEM, particularly engineering, during their K-12 studies. Quality curricular materials in these areas are scarce and teachers have not been trained to incorporate these topics into their curriculum and instruction (Kimmel, Carpinelli, Burr-Alexander, & Rockland, 2006). Therefore, students are not adequately prepared to enter STEM programs in college or pursue careers in STEM fields (NSB, 2008). As a result, there has been a growing interest in higher education to bring engineering principles and applications to secondary school mathematics and science classrooms (Kimmel & Rockland, 2002; Kimmel, Carpinelli, Burr-Alexander, & Rockland, 2006). The integration of engineering concepts and applications into the different content areas in the curriculum is one approach. The engineering design process can provide a context that would support teachers in teaching about scientific inquiry since these processes are parallel in nature and have similar problem-solving characteristics.

Robotics encompasses the diverse areas of technology, computer science, engineering, and the sciences. Because of its multidisciplinary nature, using robotics in the classroom can be a valuable tool to increase student motivation and learning. The use of practical, hands-on applications of mathematical and scientific concepts across various engineering topics will help students to link scientific concepts with technology, problem solving, and design, and to apply their classroom lessons to real-life problems.

Teachers require a certain set of skills and knowledge to begin integrating technology and engineering concepts into their classroom practices (Boettcher, Carlson, Cyr, & Shambhang, 2005; Zarske, Sullivan, Carlson, & Yowell, 2004). For new teachers this can be part of their pre-service training, but for current teachers comprehensive professional development programs are needed. Some identified factors that should be included in successful professional development programs include: long-term effort, technical assistance, and support networks, collegial atmosphere in which teachers share views and experiences, opportunities for reflection on one's own practice, focus on teaching for understanding through personal learning experiences, and professional development grounded in classroom practice.

This article provides a brief account of efforts to address the aforementioned issues and summarizes work that has been conducted at the New Jersey Institute of Technology to develop K-12 STEM curricular materials and training programs for secondary science and mathematics teachers in order to integrate engineering principles into classroom instruction.

Integrating Engineering into the Content Areas of Science

Many higher educational institutions have been working to bring technology and engineering principles into secondary school classrooms. The integration of engineering concepts into science and mathematics curriculum through interesting but practical applications helps increase students' interest in STEM, and it connects classroom lessons to the real world. Curriculum development and instructional strategies to support teachers in these efforts have been developed over the past decade (Baker, Yasar, Kurplus,.Krause, & Roberts, 2004; Beven & Raudebaugh, 2004; Contrell, Pekcan, Itani,. & Velasquez-Brant, 2006; Harwood & Rudnistsky, 2005; Kimmel & Rockland, 2002; Poole, deGrazia, & Sullivan, 2001).

Currently, available curriculum materials need to create connections between the science used in engineering applications of the real world and science curriculum standards for which teachers and administrators are held accountable. Science can be viewed as proposing explanations for questions about the natural world, whereas engineering proposes solutions for problems of human adaptation to the real world. Instruction can emphasize the interdependence of these two disciplines as well as clarify their differences. The integration of engineering principles into science instruction, presented through problem-solving inquiry/ discovery pedagogy, can stimulate students as well as enable them to recognize links between their lessons and tasks performed by engineers in the real world (Harwood & Rudnistsky, 2005). When engineering and science are taught in tandem, they extend and reinforce each other.

Although curriculum materials and instructional strategies are necessary, they alone are not sufficient. What is also needed is effective professional development training for current teachers (Kimmel, et. al., 2006; Zarske, et. al., 2004). Adequate new and pre-service teacher preparation programs (Jones & Wang, 2001), that recognize the pressure on teachers to align their instruction with state content standards needs to be addressed as well (Anderson-Roland et al., 2002; Fadali & Robinson, 1999; Loepp, 2004; Olds, Patel, Yalvac, Kanter, & Goel, 2004; Schaefer, Sullivan, & Yowell, 2003). Anderson-Roland et al. (2002) examined these issues and concluded that the system of education as well as the pressure to implement academic content standards and associated high-stakes state-wide assessments, were barriers to the degree by which science instruction and the curriculum can be changed or modified.

The Engineering Design Process and the Process of Scientific Inquiry

"Reasoning scientifically" or "thinking like a scientist" are two expressions frequently used by educators to describe the inquiry approach to teaching science. This instructional approach is reflected in the recommendations of the National Science Education Standards (NRC, 1996) as a way to introduce students to how scientists actually conduct scientific inquiry. The reasoning and thinking aspects of the scientific inquiry process encompass learning outcomes such as understanding what it means to "know" something, understanding where knowledge comes from, being able to evaluate the validity of a knowledge claim, and understanding why knowledge is never final. Despite the importance of scientific thinking, it continues to be an elusive educational outcome for students, who do not seem to grasp how scientific theories arise and the manner in which evidence is used to support or call those theories into question. Many students do not understand the inquiry process because of the way it is taught, that is, the scientific method is a recipe for a step-by-step process that scientists follow to make discoveries.

Like scientists, engineers look at and think about the real world and what counts as knowledge. The engineering design process provides a context that can support teachers in the teaching of inquiry and scientific reasoning. It helps to bridge the disciplinary boundaries between science and engineering by drawing on engineering and engineering education as well as "mainstream" science as sources of ideas for instruction (Lewis, 2006).

The thinking and problem-solving characteristic of the engineering design process is parallel to the scientific inquiry process (Barak & Zadok, 2009; Lewis, 2006). Both processes focus on how a person knows things, the strength of that knowledge, and how that knowledge is related to evidence. Engineers are constantly making judgments about design, materials, and underlying theory as they engage in problem solving. Because engineers recognize that solutions to problems are only as good as

Table 1. Comparison of the Engineering Design Process and the Scientific Inquiry Process.

Engineering Design	Scientific Inquiry
1. Identify the need or problem	1. Formulate the problem
2. Research the need of problem	2. Information gathering
3. Develop possible solutions	3. Make hypotheses
4. Select the best possible solution	4. Plan the solution
5. Construct a prototype	5. Test solutions (perform experiments)
6. Test and evaluate the solution	6. Interpret data, Draw conclusions
7. Communicate the solution	7. Presentation of results
8. Redesign	8. Develop new hypotheses

the knowledge that supports them, and that sometimes solutions must be offered with incomplete knowledge, they view making constant knowledge improvement central to their work. The engineering design process is compared with the scientific inquiry process in Table 1 (Harwood & Rudnitsky, 2005; Lewis, 2006).

Asking the right questions and answering them in the most coherent manner is at the heart of both processes. For the engineer, constructing prototypes in order to make decisions bears a close resemblance to the experimentation of the scientist; both are aimed at answering questions. Incorporating engineering principles and design concepts into science curricula in ways that meet national and state science standards requires new knowledge and changes in classroom instruction.

Professional Development

Professional development for teachers is considered a key vehicle for educational reform and the need to change and improve classroom instructional practice (Gibbons, Kimmel, & O'Shea, 1997; Guskey, 1986; Sparks, 1983). Professional development for teachers should introduce them to technological content and resources that expand their knowledge and their ability to apply new knowledge in the classroom A long-term professional development program that exposes science teachers to engineering principles and design can lead to the infusion of engineering principles and design into existing science classes that can be continued year after year and last through and beyond the training period (Zarske et al., 2004).

Some of the key factors identified for effective professional development include: engaging teachers in practicing concrete tasks related to teaching, assessment, and observation of learning; drawing upon teachers' questions, inquiry, and experiences; including time for collaboration, sharing and exchange of ideas and practices; building on teachers' current work with students; and providing modeling, coaching, and problem-solving around specific areas of practice.

The planning of professional development programs that effectively lead to desired teaching practices is not a simple process. Too often, short-term training institutes and after school workshops are seen as ends in themselves. "One-shot" approaches to staff development fail to produce lasting changes in teachers' behavior because these teachers are not provided with the opportunity to experience success. Staff development efforts often focus on isolated instructional behaviors, such as cooperative learning, teaching to learning styles, or classroom management skills.

An alternative perspective on the features influencing effective professional development outcomes is provided by Yoon and colleagues (Yoon, Garet, Birman, & Jacobson (2006), who consider five features and three core features follow: (1) Active Learning: Teachers are involved in discussion, planning, and practice, (2) Coherence: Activities are built on what they are learning and lead to more advanced work, (3) Content Focus: Content is designed to improve and enhance teachers' knowledge and skills, and two structural features follow: (1) Duration: Professional development for teachers extend over a two-year period, and (2) Collective Participation: Teachers meet in discipline and grade level groups to discuss strategies and content, and to develop approaches that they present to their peers.

Prior Efforts at NJIT

The Pre-Engineering Instructional and Outreach Program (PrE-IOP) at the New Jersey Institute of Technology's Center for Pre-College Programs was established to inform students, teachers, parents, and school counselors about careers in engineering and to provide teachers with pre-engineering modules that could be integrated into their secondary school science curricula, along with professional development on content and instructional strategies for the modules (Kimmel & Rockland, 2002; Carpinelli, Burr-Alexander, Hanesian, Kimmel, &Sodhi, 2004). The modules were developed to incorporate multiple engineering disciplines including biomedical, chemical (Hanesian, Burr-Alexander, Kimmel, Kisutcza, & Tomkins, 2004), civil, electrical and mechanical, all appropriate for integration into life and physical sciences. Survey instruments were developed to measure students' (Gibbons, et al., 2004; Hirsch, Gibbons, Kimmel, Rockland, & Bloom, 2003), teachers' (Hirsch, Kimmel, Rockland, & Bloom, 2005), parents' and school counselors' (Gibbons, et. al., 2003) attitudes engineering and knowledge about engineering careers to help evaluate the impact of the pre-engineering curriculum and the effectiveness of the PrE-IOP training programs. Teachers' attitudes and knowledge about engineering careers, their concerns about implementing the curricula, along with their self-reported preparedness to teach the new modules were examined longitudinally across two academic years. Repeated measures of analysis of variance found significant increases across the two years (Hirsch, Kimmel, Rockland, & Bloom, 2006). Students' attitudes engineering and knowledge about engineering careers were also examined and significant increases were found during the school year following teachers' training. The attitudes and knowledge about engineering careers for students taught by the same teachers during the second year after training were significantly higher than for students taught by the teachers' colleagues who taught the same classes but did not participate in the training program (Hirsch, et. al., 2006).

Medibotics: The Merging of Medicine, Robotics, and Information Technology

Because of its multidisciplinary nature, the study of robotics in the classroom can be a valuable tool for the practical, hands-on application of concepts across various engineering and science topics (Beer, Chiel, & Drushel, 1999; Eguchi, 2009). The Medibotics project was developed to use robotics as a teaching tool to increase student motivation to utilize information technology (IT) applications to learn scientific and mathematical concepts, and to link them to technology, problem solving, and design. Medibotics represents the merging of the specialties of medicine, robotics, and information technology, as it focuses on the development of projects that are medical in origin. The curriculum developed for Medibotics enables the incorporation of IT, engineering, and robotics into the science and mathematics curricula of secondary school classrooms by teaching students to design and build robots to perform simulated computer-assisted surgeries.

A professional development program aligned with the factors described by Yoon and colleagues (2006) was designed to train teachers to use the Medibotics curriculum. The program consisted of an initial two-week summer workshop, a one-week summer workshop the following summer, and an academic year follow-up that included one-day workshops and in-class support by university faculty, staff, and graduate students during their implementation process in the classroom. In addition, an electronic peer-learning community was established for communications among teachers and university personnel and for online professional development activities.

The Medibotics curriculum used LEGO™ MINDSTORMS for Schools with ROBOLAB programming software kits to solve biomedical engineering problems. The ROBOLAB software uses an icon-based, diagram-building environment to write programs, and it is based on LabVIEW™, from National Instruments, the most popular software used in biomedical engineering. This icon-based environment enables students at lower grades to perform simple to complex programming tasks. Using these types of kits to teach students to build robots provides an overview of how multiple fields of science, such as biology, medicine, engineering (sensors and motors), and physics (gears, shifts, belts, wheels, axles and hinges) can be combined with information technology (the programming languages that help support the input and output from sensors to motors) to solve real-world problems. In order to move and control their robots, students must become familiar with basic actuators, some basic motor controls, and the use of sensors to provide feedback of position.

The simulated robotic surgeries have elements of actual medical procedures. Each surgery entails a different set of tasks and sequence of actions, requiring the development of different procedures and programs using the LEGO™ MINDSTORMS for Schools with ROBOLAB programming software. The robotic surgeries have been developed to demonstrate various surgical procedures and physiological topics; to demonstrate physical forces and design principles; to utilize various sensors, and relate scientific principles to the sensors; to use common food or craft products that are inexpensive and easy to obtain and maintain (avoiding meat and nut products that need refrigeration); to enable students to understand basic programming concepts; and to demonstrate complex programming in which the robot has to perform actions based its sensors.

One teacher from the Medibotics program augmented a life science lesson with examples of how robots could be used to enhance the study of functioning parts of the skeletal system. Comparisons were made between the joints of humans and robots and their comparative flexibility. Students experienced both types of structure and how each performed based on its assets and limitations. Conversation with the instructor indicated that he planned to coordinate a robotic experience with each of the content areas in the school curriculum. Another teacher modified the ninth grade general science curriculum, so that robotics had been integrated into each of the areas of earth, physical, and life science. For example, in earth science, students programmed robots to explore the surface of Mars. Robotic surgery was introduced as an application in the life sciences.

Robotics as a Vehicle to Bring Engineering Concepts into the Science Classroom

Robotics provides many opportunities to use engineering and information technology to enhance science instruction for both the teacher and the students. The integration of robotics into the science curriculum capitalizes on the embedded science concepts (Kimmel, Carpinelli, Burr-Alexander, Hirsch, & Rockland, 2008; Chambers, Carbonaro, & Rex, 2008). The design, construction, and control of the robots by the students contribute to the learners' acquisition of knowledge and the refinement of their thinking skills regarding scientific, engineering design, and information technology. The robotic surgeries provide teachers with the opportunity to move the study of scientific concepts from the textbook to hands-on learning of biology topics, such as anatomy and physiology, and chemistry topics, such as acids and bases.

The construction and operation of the robot itself demonstrates applied physical concepts including motion of objects, levers, gears, forces, rotational torque, movement of the robotic arm (mechanics), principles of electricity and basic circuitry. Statements of expectations of students, related to these topics are provided in the State Content Standards (NJDOE, 2008). For example, Standard 5.7 (Physics): All Students Will Gain an Understanding of Natural Laws as They Apply To Motion, Forces, And Energy Transformations:

- When more than one force acts on an object at the same time, the forces can reinforce or cancel each other producing a net force that will change speed and/or direction of the object.

- Whenever one object exerts a force on another, an equal and opposite force is exerted on the first object.

While principles of applied physics would apply to any of the robotic surgeries, incorporating the Medibotics curricula into the life sciences, chemistry, and physics would depend on the specific surgery and the choice of sensor. Understanding energy including light, heat, sound, electricity, and magnetism is necessary for the use of sensors, such as the light sensor and the sound sensor, and requires knowledge of properties of light and optics, transfer of energy, and waves. Student expectations related to these topics are provided in the State Content Standards (NJDOE, 2008). For example, Standard 5.7 (Physics): All Students Will Gain An Understanding Of Natural Laws As They Apply To Motion, Forces, And Energy Transformations.

- Describe the nature of various forms of energy, including heat, light, sound, mechanical, and electrical energy transformations from one form to another.

- Explain how the various forms of energy (heat, electricity, sound, light) move through materials and identify the factors that affect that movement.

A sound sensor is essentially a microphone which is a type of transducer; an electrical component that will take a mechanical input and turn it into an electrical one. The mechanical input in this particular sensor is the pressure from sound that causes a small plate to vibrate. A light sensor is a sensor responsible for giving the robot a visible sense of its surroundings. The sensor has two main roles; the first is to gather a reading of the ambient light in the sensor's surroundings and the second is to generate a beam of light and gather a reading from the light reflected off of the surface. A color sensor doesn't measure the intensity of white light; instead, a color sensor measures the intensity of red, blue, and green light. The light sensor can only distinguish between one or two different shades of color, whereas a color sensor can distinguish each individual color, allowing one sensor to identify several different objects by color.

The robotic surgeries also can be used in biology to teach physiology and anatomy. Statements of expectations of students related to these topics are provided in the State Content Standards (NJDOE, 2008). For example, Standard 5.5 (Characteristics of Life): All Students Will Gain an Understanding of The Structure, Characteristics, And Basic Needs of Organisms and Will Investigate the Diversity of Life.

- Describe the basic functions of the major systems of the human body including, but not limited to, the digestive, circulatory, respiratory, skeletal, and muscular systems.
- Explain how systems of the human body are interrelated and regulate the body's internal environment.
- Recognize that complex multicellular organisms, including humans, are composed of and defined by interactions of tissues, organs, and systems.

One surgery simulates a heart bypass operation. From this surgery, students can learn about coronary circulation and how the coronary circulation consists of the blood vessels that supply blood to and from the heart muscle. They can also learn about the two main coronary arteries. Good heart function means that the heart will function properly. Coronary disease occurs when these relatively narrow vessels are commonly affected by a build up of plaque. As plaque builds up, the coronary arteries become narrow and stiff. Blood flow to the heart is reduced. This lack of blood flow decreases the oxygen supply to the heart muscle. The result is either angina or a heart attack. The heart bypass surgery uses "twizzlers" to represent blood vessels, the red (healthy), and the black (unhealthy). The robot is designed to perform the corresponding surgery that would move the robot to the "blood vessel", test it, and if it is healthy (red), leave it alone. If the "blood vessel" is unhealthy (black), the robot should remove it and replace it with a healthy one. Students can also discuss what happens to other systems in the body if the circulatory system performs inadequately because the heart cannot pump efficiently

Another surgery illustrates the biological principles in Fundoplication, the standard surgical method to treat gastro-esophageal reflux disease (GERD), which causes inflammation, pain (heartburn), or other serious complications. GERD causes acid to come back up from the stomach into the esophagus. Fundoplication is the surgical technique that strengthens the barrier to acid reflux by closing off the esophagus from the stomach. This surgery requires that students are able to identify and describe the functions of the major components of the digestive system, stomach, esophagus and that they learn about stomach acid; breakdown of food to pull out nutrients and energy; acid-reflux disease; and medical justifications for surgical/non-surgical treatments.

Fundoplication can also be used in chemistry so students can learn about acids and bases, the pH scale, neutralization of acids, and function of antacids. Students have the opportunity to create a mock pH scale using the color sensor, and then use it to identify the pH of the stomach acid. Experiments can be carried out to determine the effects of antacids on pH by creating a graph depicting experimental results as well as explaining which antacid had the most desirable effect. Statements of expectations of students, related to these topics are provided in the State Content Standards (NJDOE, 2008). For example, Standard 5.6 (Chemistry): All Students Will Gain an Understanding of The Structure and Behavior of Matter.

- Describe the properties of mixtures and solutions, including concentration and saturation.

- Show how substances can chemically react with each other to form new substances having properties different from those of the original substances.

Engineering in Teacher Preparation Programs

Increasing the presence of engineering in the K-12 curriculum will require more qualified and better prepared math, science, and other discipline teachers. The education of science and mathematics teachers in different content areas generally does not include courses that promote an understanding of engineering principles and design. Bringing engineering into K-12 classrooms will require modifications of programs for teachers of science and mathematics. This can be addressed by exposing teachers to pre-service training on engineering concepts that show them how they can integrate these concepts into the classroom. The approach that is most realistic "is to blend engineering concepts and exercises into math, science, and other classes in elementary, middle, and high schools" (Cavanagh, 2009, para. 11).

The training of K-12 teachers requires a viable plan that will allow more students to be prepared for careers in engineering. This is accomplished by preparing teachers to bring engineering into their K-12 classrooms by addressing five key factors: (1) Instruction; (2) Student Learning; (3) Time; (4) Resources; and (5) Training.

A framework for pre-service teachers to blend engineering concepts is Preparation, Assistance, and Reflection (PAR) (Richardson, Morgan, & Fleener, 2009), an instructional strategy that can be used to focus instruction on the learner and learner outcomes. Learners' prior knowledge and interest are critical to integrating effective engineering concepts into the curriculum. There are many ways to prepare, assist, and extend students' understanding and application of engineering learning objectives. Although PAR was developed to help teach students to read and comprehend text structures across all disciplines, herein it is considered applicable to an integrated, student-engaged and interconnected K-12 educational system for teaching engineering. Engineering lessons on how products are designed and built fit well with science, technology, and math education at the K-12 level. Students who live in the 21st century are immersed in "a world that's shaped by engineering," while in the early 1990s, "almost no engineering curricula or programs existed" (Cavanagh, 2009, para. 8). Unlike mathematics and science, engineering has no formal standards or assessment measures of student learning. The What and How of learning across the stages of PAR imparts for both teacher and student, the vibrant exchange of the learning cycle. David Small, Pentagon mechanical engineer on missile defense system states that "a key element in designing a 'pre-engineering' or engineering course, as well as teaching it, is always keeping in mind where the students are, both in life and in the learning process" (Aronowitz, 2009, para. 10).

The What of the student learning cycle are the K-12 national and state learning objectives of mathematics, science, and technology that accompany the requisite assessment measures that parallel the key trends and issues in engineering education, while the How is the interest-based engineering activities that encourage learning through PAR. The How based activities are age-, grade- and interest-appropriate hands-on learning activities that address engineering concepts through problem-based tasks that include conception (P), development (A), and the building (R) of technological gadgets, such as transistor radios, burglar alarms, electronic timers, telephones, cameras, computers, robots, bridges, go-carts, theme park rides, and roller coasters. The focus for exposing K-12 students to engineering, as it does in other successful learning endeavors, must be on student interest (Daly, 2008). Pre-service teachers need to be given the opportunity to learn how to adopt, adapt, and/or develop interest-appropriate hands-on learning activities. This is what and how lessons leap to life as Michele Miller writes in her article about fifth grade teacher Annie McCallister who developed 45-minute lab activities using simple inexpensive supplies from recycling centers and home building supply centers to capture teaching time and student interest by having students "interact with other things besides a book" (Miller, 2010, "New Science Lab," para. 7). McCallister makes her point by using her guitar to teach a lesson on sound energy. In addition, pipe insulation from a home supply store is used by students to make miniature roller coasters to understand physics. According to Samantha Murray, K-12 coordinator for the American Society for Engineering Education (ASEE), targeting middle school and high school students requires a "vigorous" integrated curriculum that creates a natural progression for learning "by getting students in the mindset of being able to think about engineering as a possibility" (McCrea, 2009, para. 6) and a career "long before it comes time to select a major" (McCrea, 2009, para. 8). The mindset can be created if educators pursue student interests while teaching and exposing students to take a product apart and put it back together or, according to Savannah, Georgia, high school educator David Small, achieve the like using "a CAD [tool] to sketch a 2D world and then manipulate it to create a 3D figure to manipulate it [onscreen] depending on what you're trying to develop" (Aronowitz, 2009, "Assembly, the Right Components," para. 17).

Knowing what and how students learn and to engage them as active learners, one must take into account the teacher who is the not the "sage on the stage," but, the "guide on the side" (King, 1993, p. 30). To successfully accomplish this learning cycle the teacher must address how students learn by acknowledging and practicing research findings from National Training Laboratories in Bethel, Maine, on types of instruction versus long-term retention (Haun, 2002). This level of learning, resulting in retention and transfer, occurs most efficiently through concrete activity-based experiences. Active learning involves input from multiple sources through multiple senses (hearing, seeing, feeling, etc.). The Learning Pyramid presents that students learn and retain 90% of new knowledge when they are engaged in purposeful activities with their peers, that is, students teach others and students immediately use and apply new information. In contrast, only 5% is learned and retained when teachers use lecture and 10% is retained when students read to themselves and use the textbook to present and learn new knowledge. It has also been stated that there is a need for core concepts and ideas with less of an emphasis on scientific steps on how to make a device or establish a process specific to a task (Cavanaugh, 2009, para. 9).

In K-12 schools the focus has unfortunately been on the topic "engineering design" at the neglect of engineering principles and processes with hands-on applications. Cavanaugh (2009) further suggests that K-12 teachers and school programs should be designed so engineering lessons ". . . ask students to make use of math, science, and technology knowledge and skills. . . and emphasize problem solving, the ability to use equipment and technology, communication and collaboration with others" (para. 10). Not withstanding that teachers are governed by the constraints of time and delivery for the courses they teach, there are governing components of teaching, that is, the strategies and techniques of the what and how of the discipline. According to Small, what makes "a good fit for the course is that even though professional engineers use it to design much more advanced components, the basic application is designed for broad use, from beginners to trained technicians to technology manufacturing professionals. . . like a calculator, its functions can be applied at all levels of education and productivity" (Aronowitz, 2009, para. 16). The what and how of learning across the preparation, assistance, and reflection stages of teaching imparts the exchange of learning for both the teacher and the student. Within the teaching and learning cycle both the teacher and student are accountable and reflective of what is learned and how as it relates to learning, application, and extension of this knowledge to new and varied settings that gives students, according to Small, "a practical idea of what may be required of them in pursuing a career they had previously decided they wanted based solely on an abstract concept of what it entailed" (Aronowitz, 2009, "Not Engineers Yet," para. 19). Roger Yancey, Headmaster of Savanna Christian Preparatory School, finds "this awareness in high school as a way of narrowing students' focus once they're in college and making long-term decisions". . . and research at Armstrong University in Savannah shows at least it reduces the number of 'change of majors' before graduating" (Aronowitz, 2009, "Not Engineers Yet," para. 20).

The key to success is assessment integrally tied to the learner and outcomes. Outcomes stated and modeled on the Preparation stage of learning and focused on a static, nonmoving target enable students to focus clearly on learning to comprehend new knowledge, thereby moving seamlessly through knowledge, comprehension, application, analysis, synthesis, and evaluation of Bloom's taxonomy of learning. The features of PAR allow students to (P) encounter new knowledge (discovered or presented), (A) have knowledge modeled with an opportunity to practice in order to verify success or, if not success, correct learned behavior by being re-taught and allowed to practice again the new knowledge, until learning has been achieved to the level of expectation for the individual and in keeping with the objective and the identified assessment measure. Additional practice of new knowledge in similar and/or diverse settings during the (R) reflection stage stabilizes the learner's intake of the new concept while the assessment, directly linked to that which occurred in the PAR phase, ensures the student and the teacher that learning has taken place. Additional exposure of the concept affords retention if the teacher revisits the concept learned in strategically planned, intermittent occurrences over ensuing 2-3 week periods. The value of the assessment to both the learner and teacher is directly related to the learning objectives and the teacher's what and how of delivery. If students learn successfully, the assessment measure validates the learning, if not, and the measure has fidelity to the course of objectives, then the teacher needs to re-teach using a different or revised set of protocols for instructional delivery. In any case, during preservice education, teachers need to learn how to reflect on their instructional decision-making, evaluate their teaching performance, and adapt their performances to ensure learners' success, and thus teachers' success. In our increasingly technological and knowledge-based competitive global society, it is critical to produce more engineers in the United States and to increase awareness about engineering in order to support and use engineering for a more efficient, effective, safe, and secure world community. The application of PAR is one framework for integrating engineering education into the K-12 curriculum.

Summary

This article contributes to the dialogue that explores best practices for bringing engineering principles and applications into the science and mathematics curricula. Areas of consideration include the development of curriculum materials and instructional strategies for classroom teachers; effective professional development for the current teachers; effective alternative preparation of new teachers; and using engineering topics to achieve state and national content standards. Prior efforts to establish effective professional development for teachers of science and mathematics are discussed. Successful programs that include specific examples have been described and should serve as models for others. Implementation of successful models should lead to a future workforce that is more technologically literate, and that ultimately includes more engineers to meet the challenges of the coming years.

Dr. Ronald Rockland is a Professor of Engineering Technology and Biomedical Engineering, and Chair of the Department of Engineering Technology at New Jersey Institute of Technology, Newark

Dr. Diane S. Bloom is an Assistant Professor in the Department of Elementary Education and Bilingual Education at Kean University, Union, New Jersey.

Dr. John Carpinelli is a Professor of Electrical and Computer Engineering at New Jersey Institute of Technology, Newark .

Ms. Levelle Burr-Alexander is a senior member of the professional staff at Center for Pre-College Programs at New Jersey Institute of Technology, Newark .

Dr. Linda S. Hirsch is a senior member of the professional staff at the Center for Pre-College Programs at New Jersey Institute of Technology, Newark.

Dr. Howard Kimmel is a professor of Chemical Engineering at New Jersey Institute of Technology, Newark, and Executive Director of its Center for Pre-College Programs.

References

Anagnostopoulos, C., Gorham, D., Newberry, P., Stoler, B., & Sechrist, C. (2001). Pre-college engineering education and standards for technological literacy. *Proceedings of the 2001 ASEE Annual Conference*, Albuquerque, NM.

Anderson-Rowland, M., Baker, D. R., Secola, P. M., Smiley, B. A., Evans, D. L., & Middleton, J. A. (2002). Integrating engineering concepts under current K-12 state and national standards. *Proceedings of the 2002 ASEE Annual Conference*, Montreal, PQ, Canada.

Aronowitz, S. (2009, June 11). Re: Engineering in the 21st century. *THE Journal*, Retrieved from. http://thejournal.com/articles/2009/06/11/engineering-21st-century-skills.aspx

Baker, D. R., Yasar, S., Kurplus, S. E. R., Krause, S. J., & Roberts, C. (2004). Not just for Nerds: Embedding sience activities with a design, engineering, and technology environment. *Proceedings of the 34th ASEE/IEEE Frontiers in Education Conference,* Savannah, GA.

Barak, M. & Zadek, Y. (2009). Robotics projects and learning concepts in science, technology and problem solving. I*nternational Journal of Technology & Design Education, 19*, 289-307.

Beer, R. D., Chiel, H. J., & Drushel, R. F. (1999). Using autonomous robotics to teach science and engineering. *Communications of the ACM, 42* (6), 85-92.

Beven, R. Q., & Raudebaugh, R. A. (2004). A model for unified science and technology. *The Journal of Technology Studies, 30* (1), 10-15.

Boettcher, B., Carlson, B., Cyr, M., & Shambhang, S. (2005). Engineering implementation in grades 6-12: Evaluation of the effectiveness of a workshop model. *Proceedings of the 35th ASEE/IEEE Frontiers in Education Conference,* Portland, OR.

Carpinelli, J., Burr-Alexander, L., Hanesian, D., Kimmel, H., & Sodhi, R. (2004) The pre-engineering instructional and outreach program at the New Jersey Institute of Technology. *Proceedings of the International Conference on Engineering Education,* Gainesville, FL.

Cavanagh, S. (2009, September 8). Panel wants engineering integrated into the curriculum. *Education Week.* Retrieved from http://www.edweek.org/ew/articles/2009/09/08/03engineering.h29.html

Chambers, J. M., Carbonaro, M., & Rex, M. (2007). Scaffolding knowledge construction through robotic technology: A middle school case study. *Electronic Journal for the Integration of Technology in Education, 6*, 55-70.

Contrell, P., Pekcan, G., Itani, A., & Velasquez-Brant, N. (2006). The effects of engineering modules on student learning in middle school science classrooms. *Journal of Engineering Education, 95*, 301-309.

Daly, T. (2008). Fly under the radar, soar as a teacher. *Special Report:7 Days to a Perfect Classroom.* San Diego, CA: Smartypants Publications.

Eguchi, A. (2009). What are students learning from educational robotics? Different approaches to educational robotics. *Proceedings of 20th International SITE Conference,* Charleston, SC.

Fadali, M. S., & Robinson, M. (1999). How do the National Science Education Standards support the teaching of engineering principles and design? *Proceedings of the 30th ASEE/IEEE Frontiers in Education Conference,* Kansas City, MO.

Gibbons, S., Kimmel, H., & O'Shea, M. (1997). Changing teacher behavior through staff development: Implementing the teaching and content standards in science. *School Science and Mathematics, 97 (*6), 302-309.

Gibbons, S. J., Hirsch, L. S., Kimmel, H., Rockland, R., & Bloom, J. (2003). Counselors attitudes and knowledge about engineering. *Proceedings of the 2003 International Conference on Engineering Education,* Valencia, Spain.

Gibbons, S. J., Hirsch, L. S., Kimmel, H., Rockland, R., & Bloom, J. (2004, October). Middle school students' attitudes to and knowledge about engineering. P*roceedings of the International Conference on Engineering Education,* Gainesville, FL.

Guskey, T. R. (1986). Staff development and the process of teacher change. *Educational Researcher, 15*, 5-12.

Hanesian, D., Burr-Alexander, L., Kimmel, H., Kisutcza, J., & Tomkins, R. P. T. (2004). Integrating chemical engineering as a vehicle to enhance high school science instruction. *Proceedings of the 2004 ASEE Annual Conference,* Salt Lake City, UT.

Harwood, J., & Rudnitsky, A. (2005). Learning about scientific inquiry through engineering. *Proceedings of the 2005 ASEE Annual Conference,* Portland, OR.

Haun, P. (2002). Active learning online learning pyramid. Bethel, Maine: National Training Laboratories.

Hirsch, L. S., Gibbons, S. J., Kimmel, H., Rockland, R., & Bloom, J. (2003, November). High school students' attitudes to and knowledge about engineering. *Proceedings of the 33rd ASEE/IEEE Frontiers in Education Conference,* Boulder, CO.

Hirsch, L .S., Kimmel, H., Rockland, R., & Bloom, J. (2005). Implementing pre-engineering curricula in high school science and mathematics. *Proceedings of the 35th ASEE/IEEE Frontiers in Education Conference,* Indianapolis, IN.

Hirsch, L. S., Kimmel, H., Rockland, R., & Bloom, J. (2006). Using pre-engineering curricula in high school science and mathematics: A follow-up study. *Proceedings of the 36nd ASEE/IEEE Frontiers in Education Conference,* San Diego, CA.

Jones, R., & Wang, E. (2001). Experiences in an engineering technology course for education majors. *Proceedings of the 31st ASEE/IEEE Frontiers in Education Conference,* Reno, NV.

Kimmel, H., & Rockland, R. (2002). Incorporating pre-engineering lessons into secondary science classrooms. *Proceedings of the 32nd ASEE/IEEE Frontiers in Education Conference,* Boston, MA.

Kimmel, H., Carpinelli, J., Burr-Alexander, & L. Rockland, R. (2006). Bringing engineering into K-12 schools: Problem looking for solutions? *Proceedings of the 2006 ASEE Annual Conference,* Chicago, IL.

Kimmel, H., Carpinelli, J., Burr-Alexander, L, Hirsch, L. S., & Rockland, R. (2008). Introducing robotics into the secondary science classrooms. P*roceedings of the 19th International SITE Conference,* Las Vegas, NV.

King, A. (1993). From sage on the stage to guide on the sde. *College Teaching, 41* (1), 30-35. Retrieved from http://www.questia.com/PM.qst?a=o&d=94305197

Lewis, T. (2006). Design and inquiry: Bases for an accommodation between science and technology education in the curriculum? *Journal of Research in Science Teaching, 43* (3), 255-281.

Loepp, F. L. (2004). Standards: Mathematics and science compared to technological literacy. *The Journal of Technology Studies, 30* (1), 2-10.

McCrea, B. (2009, March 12). Interview: Cultivating engineers in K-12. *THE Journal.* Retrieved from http://thejournal.com/articles/2009/03/12/interview-cultivating-engineers-in-k12.aspx

Miller, M. (2010, February 2). *Where lessons leap with life.* Retrieved from http://www.tampabay.com /news/education/k12/new-science-lab-at-mary-giella-elementary-brings lessons-to-life/1070095

National Research Council [NRC]. (1996). *National science education standards.* Washington, DC: National Academy Press.

National Science Board [NSB]. (2008). Science and engineering indicators 2008. Arlington, VA: National Science Foundation (NSB-08-1).

New Jersey Department of Education. [NJDOE]. (2008). Retrieved from http://www.state.nj.us/njded/cccs/

Olds, S., Patel, C., Yalvac, B., Kanter, D., & Goel, N. (2004). Developing a standards-based K-12 surricula through partnerships with university students and industry. *Proceedings of the 2004 ASEE Annual Conference,* Salt Lake City, UT.

Poole, S. J., deGrazia, J. L., & Sullivan, J. F. (2001). Assessing K-12 pre-engineering outreach programs. *Journal of Engineering Education, 90* (1), 43-48.

Richardson, J. S., Morgan, R. F., & Fleener, C. E. (2009) *Reading to learn in the content areas* (7th ed.). Belmont, CA: Thompson Wadsworth Publications.

Schaefer, M., Sullivan, J., & Yowell, J. (2003). Standards-based engineering curricula as a vehicle for K-12 science and math integration. P*roceedings of the 33rd ASEE/IEEE Frontiers in Education Conference,* Boulder, CO.

Sparks, G. (1983). Synthesis of research on staff development for effective teaching. *Educational Leadership, 41* (3), 65-72.

Yoon, K. S., Garet, M., Birman, B., & Jacobson, R. (2006). *The effects of mathematics and science professional development on teachers' instructional practice: Using professional development activity log.* Washington, DC: Council of Chief State School Officers.

Zarske, M., Sullivan, J., Carlson, L., & Yowell, J. (2004). Teachers teaching teachers: Linking K-12 engineering curricula with teacher professional development. *Proceedings of the 2004 ASEE Annual Conference,* Salt Lake City, UT.

Acknowledgments

The discussion of the Medibotics project is based upon work supported by a grant from the National Science Foundation under Grant No. 0624434. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation (NSF).

The 2009 Paul T. Hiser Exemplary Publication Award Recipient

Steven Holley

“Nano Revolution – Big Impact: How Emerging Nanotechnologies Will Change the Future of Education and Industry in America (and More Specifically in Oklahoma) An Abbreviated Account”

The Board of Editors of The Journal of Technology Studies and the Board of Directors are pleased to announce the recipient of the Paul T. Hiser Exemplary Publication Award for Volume XXXV, 2009.

The Board of Directors established this award for deserving scholars. In recognition for his exemplary service to the profession and to the honorary as a Trustee and Director, the award bears Dr. Hiser’s name. It is given to the author or authors of articles judged to be the best of those published each year in this journal.

Selection Process

Each member of the Editorial Board recommends the manuscript that he or she considers the best of those reviewed during the year. The board nominates articles based on their evaluation against specific criteria. A majority vote of the editors is required for the award to be made. The honor society’s Board of Directors renders final approval of the process and the award.

Criteria

1. The subject matter of the manuscript must be clearly in the domain of one or more of the professions in technology.

2. The article should be exemplary in one or more of the following ways:
    - Ground-breaking philosophical thought.
    - Historical consequence in that it contains significant lessons for the present and the future.
    - Innovative research methodology and design.
    - Trends or issues that currently influence the field or are likely to affect it.
    - Unique yet probable solutions to current or future problems.

A $300 award recognizes the recipient(s) for the year and is presented during an Epsilon Pi Tau program at an annual professional association conference.

GUIDELINES FOR The Journal of Technology Studies

A refereed publication of Epsilon Pi Tau the international honor society for professions in technology.

The Journal of Technology Studies (JOTS) is the flagship, peer-reviewed journal of Epsilon Pi Tau, an international honor society for technology professions. Two print issues per year are mailed to all members of the society as well as to academic and general libraries around the globe. These printed issues, plus additional issues available only in electronic format as well as past issues, are available free on-line at scholar.lib.vt.edu/ejournals/jots.

SUBJECT FOCUS

The JOTS welcomes *original* manuscripts from scholars worldwide focused on the depth and breadth of technology as practiced and understood past, present, and future. Epsilon Pi Tau, as perhaps the most comprehensive honor society among technology professions, seeks to provide upto-date and insightful information to its increasingly diverse membership as well as the broader public. Authors need not be members of the society in order to submit manuscripts for consideration. Contributions from both academics and practitioners are equally welcome.

A general guide to the breadth of topics of potential interest to our readers can be gained by consideration of the 17 subclasses within "Technology" of the classification scheme of the Library of Congress, USA <lcweb.loc.gov.catdir/cpso/lcco/lcco_t.pdf>. This includes engineering and allied disciplines, informatics in its many manifestations, industrial technology, and education in and about technology. Authors are strongly urged to peruse this list as they consider developing articles for journal consideration. In addition, JOTS is interested in manuscripts that provide:

- brief biographical portraits of leaders in technology that highlight the difference these individuals made in distinct fields of technology or its wider appreciation within society,
- thoughtful reflections about technology practice,
- insights about personal transitions in technology from formal education to the work environment or vice versa,
- history, philosophy, sociology, economics, and anthropology of technology,
- technology within society and its relationship to other disciplines,
- technology policy at local, national, and international levels,
- comparative studies of technology development, implementation, and/or education,
- industrial research and development,
- new and emerging technologies and technology's role in shaping the future.

Within this immense diversity of technology, its applications and import, authors must communicate clearly, concisely, informatively, and only semi-technically to readers from a diverse set of backgrounds. Authors may assume some technical background on the part of the reader but not in-depth knowledge of the particular technology that is the focus of the article. Highly technical articles on any field of technology are not within the purview of the journal. Articles whose subject focus has been extensively explored in prior issues of the journal are only of potential interest if they: 1) open up entirely new vistas on the topic, 2) provide significant new information or data that overturns or modifies prior conceptions, or 3) engage substantially one or more previously published articles in a debate that is likely to interest and inform readers. Syntheses of developments within a given field of technology are welcome as are metanalyses of research regarding a particular technology, its applications, or the process of technical education and/or skill acquisition. Research studies should employ methodological procedures appropriate to the problem being addressed and must evince suitable design, execution, analysis, and conclusions. Surveys, for example, that exhibit any or all of the following characteristics are of no interest to the journal: 1) insufficient awareness of prior research on this topic, 2) insufficient sample size, 3) improper survey design, 4) inappropriate survey administration, 5) high mortality, 6) inadequate statistical analysis, and/or 7) conclusions not supported by either the data or the research design employed. The journal is neutral in regards to qualitative, quantitative, or mixed method approaches to research but insists on research quality.

GUIDELINES FOR The Journal of Technology Studies (Continued)

GUIDELINES FOR SUBMISSION

Articles must conform to the most current edition of the Publication Manual of the American Psychological Association. All articles must be original, represent work of the named authors, not be under consideration elsewhere, and not be published elsewhere in English or any other language. Electronic submissions in either rich-text format or Microsoft Word formats are encouraged, although submission of three printed copies and a diskette containing the article are also permissible. E-mail submissions should be sent to the editor, Dr. Dominick Fazarro, at jots@bgsu.edu. Paper submissions should be mailed to:

Editor, Journal of Technology Studies
Epsilon Pi Tau, Technology Building
Bowling Green State University
Bowling Green, Ohio 43403-0296

Manuscripts should be no more that 25 pages, double spaced, including references. Typescript should be *Times New Roman* or a close approximation of font and 12 point. Only manuscripts in the English language will be accepted and they should conform to American usage. Figures, tables, photographs, and artwork must be of good quality and conform to APA form and style.

REVIEW PROCESS

Articles deemed worthy by the editor for consideration by Authors who submit an article that does not merit review by the editorial board are informed within approximately two weeks of receipt of the article so that they may explore other publishing venues. A rejection may be based solely on the content focus of the article and not its intrinsic merit, particularly where the topic has been extensively explored in prior JOTS articles. Articles that exhibit extensive problems in expression, grammar, and spelling are summarily rejected. Authors of articles that have been peer-reviewed are informed within about three months from the date of submission of the article. Anonymous comments of reviewers are provided to authors that are invited to submit a revised article for either publication or a second round of review. The editor does not automatically provide reviewer comments to authors whose articles have been rejected via the peer review process but makes a judgement based on whether the feedback might prove beneficial to the authors as they pursue other publishing opportunities.

PUBLICATION

Authors whose articles have been accepted, will have their final products published in the on-line version of the journal. Selected articles from the on-line edition of the journal may also appear in two print issues that are issued per calendar year. All authors will receive a pdf version of their published article and co-retain rights to that article along with Epsilon Pi Tau. The editor will supply when requested information about an accepted article that has not yet appeared in print for faculty undergoing tenure review.

Epsilon Pi Tau

Technology Building
Bowling Green State University
Bowling Green, OH 43403-0296

Forwarding and Address Correction Requested