Technology Education/Engineering Education: A Call for Collaboration

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Abstract – *Globally, Colleges of Engineering are placing more and more emphasis on engineering education. The desire to improve engineering pedagogy and the saturation of some fields of engineering is a call for collaboration. Several National Science Foundation "Bridges for Engineering" planning grants have been awarded to provide funding for collaboration to improve engineering faculty's pedagogy and classroom methods. This paper discusses that call for collaboration and suggests that technology education is the group that will provide engineering faculty with innovative practices in teaching. A brief history of collaborations is revealed and to convince engineering faculty that technology education is the appropriate vehicle, technology education and engineering education are defined and compared. Literature reviews reveal that technology educators have been teaching engineering concepts for over 100 years. Herein, the need for technology education/engineering education collaboration is discussed. Collaboration initiation and implementation strategies of current K-12, post-secondary, and professional models are presented. National Academy of Engineering president, William A. Wulf, endorses technology education as the vehicle to implement change; therefore, recommendations from the literature are made. Conclusions drawn indicate action is necessary on the part of technology educators and engineering educators alike.*

Index Terms – *collaboration, engineering education, systemic change, technology education*

INTRODUCTION

Current initiatives in engineering education call for collaboration between colleges of engineering and their faculty and students and kindergarten through twelfth (K-12) grade teachers and students. Current initiatives in technology education call for all K-12 students to become technologically literate. Specific support for both these goals comes from the National Academy of Engineering (NAE)'s Committee on Technological Literacy. The context for technological literacy is "direct, hands-on experience with technology" [36]. Because "most people" [36] do not possess a general familiarity with technology, the need for K-12 technological experience is essential for accommodating all Americans and preparing them for the increasingly technological world in which we live. Such a task may seem daunting for any single facet of education; hence the need for collaborative efforts in developing partnerships among disciplines.

Colleges of engineering have been collaborating with non-engineering or liberal arts colleges and universities since 1903 [5]. For example, the "Three-Two Plan" was developed in an effort to better educate engineers as managers and administrators. Armsby noted one problem of engineering curricula to be the allocation of time in undergraduate engineering education between the liberal and the technical subdivisions [5]. The issue is that current curricula do not adequately prepare engineers for the technological workforce. Yet, "the last major curriculum change in engineering, the move to what is referred to as 'engineering science,' occurred following WWII" [49]. One reason for this may be that the needs required to keep programs on the cutting edge are "broadly cast, technically volatile, expensive to deliver and require several years of preparation time" [28]. The nature of engineering technology and technology education may be brought into focus through understanding of the needs that drive it. "The educational paradigm that has evolved to achieve the desired teaching and learning outcomes has mixed these factors with local industrial demand and collaboration, available educational infrastructure and the economic environment to create and sustain viable technology programs" [28].

WHAT IS TECHNOLOGY EDUCATION?

Having evolved from industrial arts education, there are many definitions of technology education. One that clearly stands out is that of the International Technology Education Association (ITEA) [21]: Technology education is "a study of technology, which provides an opportunity for students to learn about the processes and knowledge related to technology that are needed to solve problems and extend human capabilities" [21]. But, what is technology per se? In the report, *Technically Speaking: Why All Americans Need to Know More About Technology*, technology is described as "the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves" [36]. Modern technology is the result of intricate interactions among engineering, science, law, ethics, politics, and other factors [36].

Equally important to understanding the definition and purpose of technology education is to understand what technology education is not. It is not vocational education, currently known as career and technical education, which traditionally focuses on job skills development, and preparing students to enter the workforce immediately upon graduation from high school [35]. Likewise, technology education is not educational or instructional technology (IT). IT supports the effective *use* of technology in education [44]. "The term technology is often used by itself to describe the educational application of computers in a classroom; [however] instructional technology is a subset of the much broader field of technology" [27]. IT is only a small part of the study of technology. Technology education encompasses six major systems: Power and Energy, Transportation, Construction, Manufacturing, Communication, and Biotechnology, and is a study of the human-made world in which students are engaged in solving practical problems [25]. Students "design, construct, and evaluate their solutions. Just as there is no single best automobile, can opener, or building design, there is no single best solution to any of the problems that the students encounter" [25]. The focus of technology education is to ensure technological literacy for all students, kindergarten through twelfth grade.

WHAT IS ENGINEERING EDUCATION?

As an endeavor, engineering is the science and art of applying mathematical and scientific principles, experience, judgment, and common sense to design things that benefit society and humankind and solve practical problems. In general, engineers are fascinated by questions of why and how things work. As a discipline, engineering schools began to assume greater importance in the latter part of the 19th century in the United States. As understanding of the complexities of the physical world increased over time, a number of subfields developed to address the various problems inherent in different materials and applications. Thus developed the traditional primary engineering subdivisions: chemical, civil, electrical, and mechanical. Over time, specific educational programs developed to train engineers in each of these and other subfields [17]. Largely, engineers use their training in mathematics, physics, biology, and chemistry to understand the physical world and develop creative solutions to society's complex needs.

In engineering programs, there are many different methods of education. Generally, "engineering degrees prepare students in the principles and theories needed to plan, design, and create new products" [14]. According to William A. Wulf, NAE President, "Engineering is synthetic -- it strives to create what can be" [49]. In an interview with Vicky Hendley, Woodie Flowers, the Pappalardo Professor of Mechanical Engineering at the Massachusetts Institute of Technology, describes engineering as "a process in which one solves problems through an understanding of nature and people" [19]. "Through genuine commitment to teacher and student development, program development, teaching innovations and community service" excellence in engineering education may be achieved [41].

More specifically, degrees in engineering technology, which is also known as engineering fundamentals, and more recently, engineering education, differ from engineering degrees in that students learn "technical methods and practices enabling them to apply technology to the solutions of industrial problems" [14]. "Engineering [education] is tied closely to the application of vetted engineering and science laws, principles and methods to implement technological processes and operations with knowledge and skill, such as manufacturing operations" [28].

COMMONALITIES BETWEEN DISCIPLINES

Technology education and engineering education have many similar characteristics and defining principles (Table 1). Certainly, "many references use engineering and technology synonymously. Both engineering and technology treat solving practical problems as their philosophical nucleus" [12]. Engineers and technologists strive to design and manufacture useful devices and materials (technologies). The purpose of these technologies "is to increase our efficacy in the world and/or our enjoyment of it" [27]. Upon further examination of the separate features, the two disciplines begin to enmesh. For instance, LaPorte and Sanders report that general technology courses have been developed at the post-secondary level from influences such as "engineering programs that saw a need for the general public to become more informed about technological issues" [25].

Technology	Engineering
Involved with our human created and controlled world.	Involved with utilizing the materials and forces of nature for the benefit of mankind.
Employs the "Engineering Design Method" to solve practical problems.	Employs the "Engineering Design Method" to solve practical problems.
Studies the processes of technological systems.	Studies the processes of technological systems.
Guided by trial and error or skilled approaches derived from the concrete.	Guided by a more theoretical study with specific solutions recommended.
Relates to application, invention, innovation, design, and engineering.	Relates to application, invention, innovation, design, and technology.
Dependent on Engineering, Mathematics, and Science.	Dependent on Technology, Mathematics, and Science.

TABLE 1
COMMONALITIES BETWEEN DISCIPLINES [12]

THE NEED FOR TECHNOLOGY EDUCATION/ENGINEERING EDUCATION COLLABORATION

Albert A. McHenry, Professor and Dean, College of Technology and Applied Sciences, Arizona State University East, characterizes engineering technology [education] as one of two undergraduate levels of technology education, with the other being industrial technology [28]. Engineering, states Stephen Johnston, Alison Lee, and Helen McGregor, is an academic discipline founded upon and validated by engineering science [24]. In the United Kingdom, engineering tends to be viewed as the applied branch of natural science. One consequence is that, while engineering teaching and scholarship have remained closely connected with the academic disciplines of science, to a large extent they have remained isolated from the pragmatics of engineering as a professional practice [24].

On the contrary, Wulf says, "Engineering is not applied science. To be sure, [the] understanding of nature is one of the constraints [engineers] work under, but it is far from the only one, it is seldom the hardest one, and almost never the limiting one" [49]. He also reminds us that the engineering discipline is changing and the need for reform in engineering education is "urgent" [49]. Teresa L. Hein claims "college and university engineering educators have an obligation to foster science and technology literacy" and "that obligation extend[s] beyond engineering-bound and engineering students to include all elementary, secondary, and postsecondary school students" [18]. If children are "to be able to cope in our increasingly technological society, it is vitally important that they have well-grounded math and science skills. Engineers and engineering faculty can and should play a critical role in improving math and science instruction at all levels" [43].

Collaboration Initiation

"Traditionally, engineering education books describe and reinforce unchanging principles that are basic to the field. However, the dramatic changes in the engineering environment during the last decade demand a paradigm shift from the engineering education community" [29]. "Engineering graduates will have to be equipped with comprehensive knowledge in technology, science, and they will have to acquire practical skills for the protection of the environment" [42]. "During the years immediately following the launch of Sputnik [October 4, 1957], the United States overhauled its education system to encourage the training of science and engineering specialists needed to meet the technological and military challenges presented by the Soviet Union" [7]. Generally, engineering education has not kept up with the changing environment. "I think it is only a slight exaggeration to say that our students are being prepared to practice engineering in a world that existed when we were trained a generation or two ago" [49]. Hein accounts, the National Science Foundation (NSF) report [32], *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology* [NSF 96-139], "emphasizes the idea that all education is linked: 'So these sectors have mutual obligations to each other, and the fulfillment of these obligations is essential for the health of the whole'" [18].

BARRIERS AND CHALLENGES TO A FULL COLLABORATION

While there is a logical connection between engineering education and technology education, many issues present challenges and barriers to an effective collaboration. Specific barriers and challenges addressed here include systemic, cultural, and student outcomes issues: Accreditation criteria, education and training, university reward systems, occupational prestige and elitism, and learning styles and retention.

The Accreditation Board for Engineering and Technology (ABET, Inc.), the "recognized accreditor for college and university programs in applied science, computing, engineering, and technology, currently accredits some 2,500 programs at over 550 colleges and universities nationwide." (ABET). The National Council for Accreditation of Teacher Education (ABET) "accredits schools, colleges, and departments that measure up to national standards" [30]. In 2004, NCATE accredited over 550 schools, colleges, and departments of education, in which approximately 20 are technology education programs. While there is extensive overlap in terms of the general criteria for accreditation of engineering and technology education programs, the fact that there are two different accrediting organizations results in a disconnect between the two disciplines, including differences in evaluative criteria and procedures. While historically technology educators have received extensive pedagogical training as part of their education, post-secondary engineering educators have not. In other words, in general, Ph.D. engineers in academe are not educated and trained in teaching methodology.

Another barrier to full collaboration relates to the context in which engineering education and technology education programs are located. Many Research I institutions offer engineering education programs while very few technology education programs are found at Research I institutions. The primary mission of Research I institutions is research with teaching taking on secondary importance. On the other hand, most technology education programs are located at institutions where the primary mission tends to be teaching. The system of rewards, including criteria for promotion and tenure, varies depending on the stated mission of the institution.

One definition of culture is the set of shared attitudes, values, goals, and practices that characterizes an organization. Depending on its location, mission and other features, an institution of higher learning has a tendency to exhibit its own culture. Whether a prospective student will choose to attend that institution may depend on the "institutional fit," a term that describes the match between a person's attitudes, values, goals, etc. with that of the institution. Furthermore, through the process of education and training, the members of a specific discipline acquire their own culture, language, and symbols, and use their own artifacts and tools in that process. The phenomenon of "weeding out" has been used to describe the somewhat covert process by which potential members of a discipline fail to become acculturated within that discipline.

Since the end of World War II, occupations have been rated and situated on a continuum of occupational prestige [34]. Medicine, law, and engineering "professions" tend to be assigned the highest levels of prestige. Perceptions of prestige and hierarchy can result in a sense of elitism among those members higher on the hierarchy and a sense of inadequacy among those lower on the hierarchy. Teaching, particularly at the K-12 level, is assigned relatively less prestige than the aforementioned professions. This may explain in part why many engineering faculty at the post-secondary level have resisted the association of "engineering" with that of "education." Such a systemic change and reform can instill fear related to loss of prestige and to change itself. Traditionally, engineering education has focused on imparting theoretical knowledge, at least within the first two years of study, while technology education has focused on imparting the skills and knowledge necessary for practical applications. With engineering education, only those students who demonstrate outstanding stick-to-itiveness are retained through degree completion. Many will drop out during the first two years of study, and average retention rates in the 50-60% range among all engineering education programs across the nation demonstrate the difficulties inherent in academic success at the university level. Most of those students who initially choose engineering as a major will drop out or transfer to other disciplines; in many cases, these students will transfer to disciplines which offer a greater focus on applications, such as technology education, or disciplines which tend to be more people-oriented.

Oftentimes those students who struggle academically possess visual and kinesthetic learning styles and do not respond well to pedagogical methodology in which instructors primarily lecture to students. Informal assessment of learning styles among probationary engineering students at Virginia Tech revealed that the academic performance of those students who were kinesthetic learners could have improved with an "applications first, theory second" model of learning. Rather than assess learning styles and other factors relevant to poor academic performance, engineering faculty are sometimes all too quick to weed out poor performers. This is in part due to a limited knowledge of the processes of educational assessment and a sheer lack of time related to an already overwhelming commitment to the institution's expectations of research, teaching, and service.

Even those students who persist to degree completion often express dissatisfaction related to the manner in which engineering is traditionally taught with a focus on imparting theory before applications. For example, after completing his first two years of study, an Electrical Engineering honors student commented, "My friends and family all expect that I would know how to fix a toaster or a light switch. To tell the truth, I don't know how to fix either one." This particular student was optimistic that he would learn how to apply the theoretical knowledge gained during his first two years of study during an upcoming cooperative education experience. In many cases, hands-on applications are not experienced until the junior or senior year of study when students are taking capstone and senior design courses. Two Electrical Engineering seniors who mentored high school students on a FIRST Robotics team, questioned, "Why haven't we had the opportunity to be involved in this type of hands-on learning before now?"

Collaboration Implementation

Technology and engineering work in conjunction with science and mathematics to expand our capacity to understand the world (Figure 1) [27]. Engineering retains a symbiotic relationship with science and technology. The movement towards fundamentals created by the Grinter Report [1952] emphasizes both natural sciences and engineering sciences in engineering education. Teaching fundamentals and principles in engineering provide a stable core content in an ever changing technological world [12].

Connecting the domains of natural science with mathematical study and with one another, and then to practical applications through technology and engineering should be one goal of science education" (Figure 2) [27]. However, in the past, engineering programs in colleges and universities have had little influence on K-12 students who were potentially interested in engineering education and engineering careers [33].

The Committee on Undergraduate Science Education's primary goal states, "Institutions of higher education should provide diverse opportunities for *all* undergraduates to study science, mathematics, engineering, and technology as practiced by scientists and engineers, and as early in their academic careers as possible" [7]. This goal "is based on five years of research and discussions with members of many sectors of the higher education SMET community, including two years of intensive research into and consultations about major issues in SMET undergraduate education" [7]. Furthermore, the Federal Coordinating Council for Science, Engineering, and Technology's Committee on Education and Human Resources indicates that for implementation to occur progress toward milestones must be monitored and institutions must aggressively "seek opportunities for collaboration and cooperation in achieving the goals" of SMET [15].

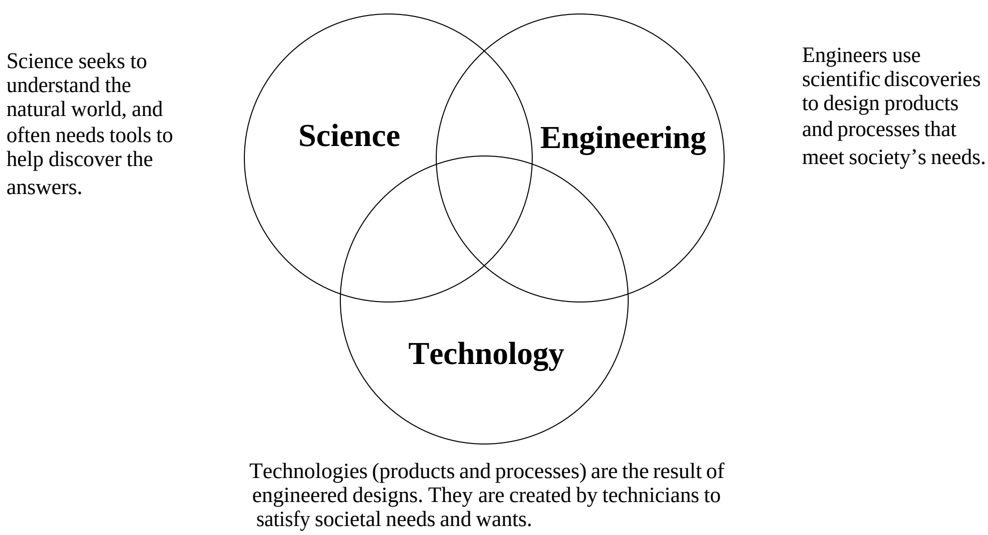

FIGURE 1
THE RELATIONSHIP AMONG SCIENCE, ENGINEERING, AND TECHNOLOGY [27].

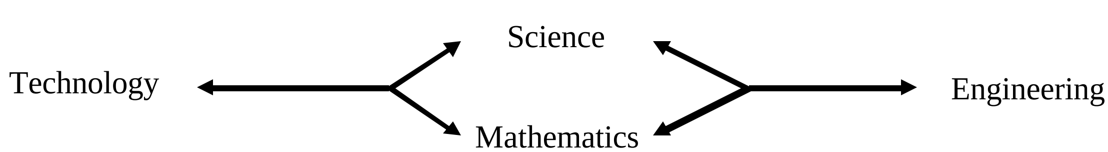

FIGURE 2
CONNECTING THE DOMAINS.

Collaboration Sustainability and Assessment

"There have been so many attempts to introduce programs of large-scale reform to education, especially in the K-12 sector, that many [engineering] faculty have adopted a 'this, too shall pass' attitude" [7]. Engineering educators often complain that students exhibit a lack of preparation in math and science when they first arrive on campus [43]. On the one hand, many of these educators fail to realize the developmental stages of the students and the associated tasks related to identify development and transition to a new environment. Furthermore, “as engineering faculty we usually assume an attitude of ‘it’s not my problem’ when it comes to improving pre-college math and science instruction or addressing diversity issues” [43]. However, collaboration among educators is elemental [18]. If a collaborative effort is to evoke change, that effort must be an institution *and* a community with its own culture (Figure 3) [10]. Educational reform can be accomplished when all groups with a vested interest in education are involved in forging the collaboration to stimulate partnerships [15]. College and university administrators must assist in the call for action by encouraging meaningful partnerships between their institutions and K-12 communities in their respective regions. They must also connect with business and political leaders in shaping an agenda for action [40]. The focus needs to be on diversity, curriculum, and pedagogy. “We need to seriously consider the need for formalized lifelong learning, the adequacy of student preparation in grades K-12, and the importance of technological literacy in the general population” [49].

McHenry indicates assessment as the emerging direction of engineering technology and technology education. “Students must have the opportunity to operate in [a] real or closely simulated environment” [28]. One assessment instrument known as the Reformed Teaching Observation Protocol (RTOP) is “standards-based, inquiry oriented, and student centered” [16]. It was found to have “a high interrater reliability and internal consistency,” but “what is promising to reform endeavors is the predictive ability of the RTOP instrument to show that highly reformed classrooms enhance student achievement” [16].

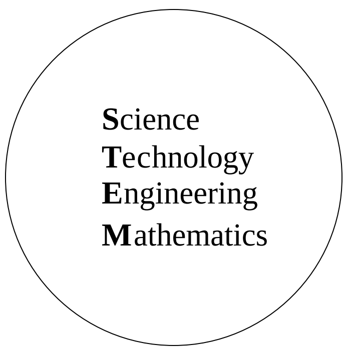

FIGURE 3
THE STEM COMMUNITY

TECHNOLOGY EDUCATION’S CONTRIBUTIONS TO K-12 ENGINEERING EDUCATION

Technology educators in secondary and middle level school systems have been conceptualizing and implementing engineering concepts into the classroom for more than one hundred years. Noted contributors include James Russell (1909), Frederick Bonser and Lois Mossman (1923), William Warner (1947), Delmar Olsen (1957), Donald Lux and Willis Ray (1970), and Donald Maley (1973), to name a few. More recently, efforts have reemerged to integrate technology education and engineering education at the elementary level.

Elementary Education

Before compulsory education exceeded eighth grade, Lois Mossman was a proponent of industrial arts in elementary schools. Sharon A. Brusic's *Mission 21* program “promotes technological literacy in the elementary classroom” [6]. Through a problem-solving approach, students in grades 1-6 study a wide range of topics (Table 2).

Grade Level	Topics of Study
1-2	Transportation, Explore, Design, and Space
3-4	Machines, Discovery, Community, and Connections
5-6	Communication, Space Colonization, Invention, and Energy/Matter

TABLE 2
MISSION 21 TOPICS OF STUDY [6]

Presently, more educators are involved in supporting the drive for technology education at the elementary level. Leaders in this area are Brusic, Dunlap, Dugger, and LaPorte (1988), Barnes, Wiatt, and Bowen (1990), Braukmann (1993), Mahlke, (1993), and Wright and Foster (1999).

Secondary Education

Likewise, many efforts exist at the secondary level. "A good model for the high school may be what Virginia is doing with some of its upper secondary school courses (usually grades 11 and 12) in *Introduction to Engineer ing*" [12]. Technology teachers usually teach these courses in secondary school programs [12].

Technology, Science, Mathematics (TSM) Curriculum Materials

The *TSM Connection Activities* bring together technology, science, and mathematics. Students learn hands-on application involving scientific and mathematical concepts. Additionally, they learn the scientific and mathematical theories behind technological devices [26]. Intended to supplement existing curricula, *TSM* activities engage students in the design, construction, and evaluation of technological solutions to specific posed problems. "In the process of designing, constructing, and evaluating their solutions, students actively apply principles and concepts studied in technology, science, and mathematics classes" (Table 3) [26].

Features	Connection Activities
A Design Brief	The Power Boat
An Overview	The Composite Beam
Technology Component	Cabin Insulation
Science Component	MagLev Vehicle
Mathematics Component	The Plant Plant
Reproducible materials (handouts and transparency masters)	The Rocket

TABLE 3
THE TSM CONNECTION ACTIVITIES [26]

Project Lead the Way (PLTW)

"Forging new generations of engineers" is the catch phrase for the National Alliance for Pre-Engineering Programs' *PLTW*. This curriculum is divided into two levels. The middle school level *Gateway to Technology* purposes "to expose students to a broad overview of the field of technology and its related processes" [37]. This action oriented course has been designed because engineers use mathematics, science, and technology to solve problems. Four ten-week units include: Design and Modeling; The Magic of Electrons; The Science of Technology; and Automation and Robotics. *PLTW* recommends that these units "be taught in conjunction with a rigorous academic curriculum" [37].

The high school pre-engineering curriculum is a sequence of courses which, when combined with traditional mathematics and science courses over a four year period, "introduces students to the scope, rigor, and discipline of engineering prior to entering college. However, those not intending to pursue further formal education will benefit greatly from the knowledge and logical thought processes that result from taking some or all of the courses provided in the curriculum" [38]. These courses are divided into three groups (Table 4).

Foundation Courses	Principles of Engineering
	Introduction to Engineering Design
	Digital Electronics
Specialization Courses	Computer Integrated Manufacturing
	Bio-Engineering (in development)
	Civil-Architectural (in development)
	Telecommunications (in development)
Capstone Course	Engineering Design and Development

TABLE 4
PROJECT LEAD THE WAY HIGH SCHOOL COURSES [38]

The Massachusetts Science and Technology/Engineering Curriculum Framework

The Massachusetts Department of Education released its Science and Technology/Engineering curriculum framework in May 2001. An initial science and technology framework had been approved and implemented in 1995. To make updates for the current revision, references were made to data from the *Third International Mathematics, and Science Study* (TIMSS), the *Technology for All Americans Project*, the *Benchmarks for Science Literacy – Project 2061*, the National Research Council's *National Science Education Standards*, "results from the 1998 administration of the MCAS [Massachusetts Comprehensive Assessment System], and advances in science and technology/engineering" [27].

Since many "skills, habits of mind, and subject matter knowledge" are required for the study of science and technology/engineering, the purpose of this document is to guide K-12 educators, enabling "students to draw on these skills, habits, and subject matter knowledge for informed participation in the intellectual and civic life of American society, and for further education in these areas if they seek it" [27]. Massachusetts' science and technology/engineering education is directed by ten guiding principles. These principles offer recommendations for creating "educational environments characterized by curiosity, persistence, respect for evidence, open-mindedness balanced with skepticism, and a sense of responsibility" (p. 1). For example, Guiding Principle II reads, "An effective science and technology/engineering program builds students' understanding of the fundamental concepts of each domain of science and their understanding of the connections across these domains and to the basic concepts in technology/engineering" [27]. Guiding Principle III reads, "Science and technology/engineering are integrally related to mathematics" [27]. Models of teaching and learning, administration, and assessment are also fashioned.

During a child's development of awareness, Pre K-5th grade, the Technology/Engineering strand focuses on two broad topics: *Materials and Tools*, and *The Engineering Design Process*. For grades 6-8, more exploratory topics about *The Designed World* are added to the framework: Communication, Manufacturing, Construction, Transportation, and Bioengineering Technologies. Communication, Manufacturing, Construction, and Energy and Power Technologies: Fluid, Thermal, and Electrical are more detailed in full-year courses for high school students. Overall, 36 standards are addressed in grades Pre K-12.

Post-Secondary Education Collaborations

Several colleges and universities have begun to initiate and implement collaborative processes. They represent different levels of focus and various stages of implementation. For instance, the *Pacific Northwest Regional Roundtable* was co-founded in 1998 by the University of Washington, Oregon State University, The Boeing Company, and the Hewlett-Packard Company. Cumulatively, this project boasts support from 50 academic, government, and industry leaders [13]. In 2002, the University of Cincinnati introduced *Project STEP* (Science and Technology Enhancement Project) that includes a summer NSF *Research Experience for Undergraduates* [8]. Currently, Utah State University is working on a general K-12 engineering and engineering education program [45]. The Penn State University began international collaborations in 1994 with the Béthune campus of the Université d Artois in northern France. This effort "now embraces faculty exchanges, joint conferences, short-term student industrial placements, distance education and teleconferencing, and research collaboration" [11].

Digital libraries have also been established. The NSF National Science, Technology, Engineering, and Mathematics Education Digital Library (NSDL) Program began in 2002. Its purpose is "to build a national library of high quality science, technology, engineering, and mathematics (STEM) educational resources for students and teachers at *all* levels, in both formal and informal settings" [51]. Zia expects the program "will encourage and sustain continual improvements in the quality of STEM education for all students, and also serve as a resource for lifelong learning" [51]. At this point, two other collaborative programs in the United States merit exploration.

The Michigan Technological University Collaboration

In 1998, the Michigan Technological University's (MTU) College of Engineering received a NSF Action Agenda grant that included three major thrust areas focused on "bringing engineering applications into the pre-college classroom" [43]. This grant was followed in 1999 with the Mathematics Department engaging in the *NSF GK-12 Teaching Fellows* program. Graduate students majoring in engineering, mathematics, or science placed in local school districts would "assist teachers in the development of K-12 mathematics and science courses and programs that more closely aligned with what is recommended by state and national standards" [43].

Ultimately, in 2000, the College of Engineering implemented the *Collaborative for Excellence in Teacher Preparation (CETP)*. The three initiatives of this grant were: 1) An Introduction to Engineering Workshop for K-12 Teachers, which entails integrating engineering into teacher education; 2) Michigan Tech's GK-12 Teaching Fellows in Copper County

Schools, including a Bachelor of Science in Engineering and Teacher Certification degree program; and 3) Engineering Applications in Pre-College Education, focusing on professional development for current teachers through engineering applications. Sorby and Baartmans perceive that many students would like to take their engineering expertise and apply it to a career in teaching. "A dual engineering and teacher certification degree program would provide more career choices for engineering majors and provide an alternative for those who after 2 or 3 years of studying engineering, decide that they really don't want to be engineers after all" [43]. MTU's *Bachelor of Science in Engineering and Teacher Certification* degree program will allow students "to complete an ABET [Accreditation Board for Engineering and Technology] accredited engineering degree and at the same time complete teacher certification in math, technology and design, and one of the sciences" [43].

National Science Foundation (NSF) Bridges for Engineering

In 2002, the NSF accepted proposals for a planning program called *Bridges for Engineering*. This grant program is "a collaboration effort between the Directorate for Engineering (ENG) and the Directorate for Education and Human Resources (EHR)" (National Science Foundation, 2002, Synopsis). The focus was opportunity for improvement in three areas: 1) The engineering content in K-12 education; 2) The pedagogy in undergraduate engineering; and 3) Engineering technology degree programs. Objectives of the grant include the increase of engineering content in pre-service teacher and general education programs of study, and to "improve pedagogy and evaluation in undergraduate engineering programs" by allowing "increased interactions among engineering and education faculty" [32]. It is expected that collaborations will demonstrate to current and future teachers "that the use of stimulating engineering concepts to illustrate real-world applications of mathematics and science increases pre-college student interest and motivation while encouraging increased numbers of pre-college students to enroll in engineering degree programs" [32].

At Virginia Tech, Mark Sanders, Professor, Technology Education, Vinod Lohani, Associate Professor, Engineering Fundamentals, and other engineering and education faculty propose the development of a new technology education masters/licensure program for engineering graduates by collaborating to increase K-12 engineering content. They also intend to develop a framework for improving engineering pedagogy at Virginia Tech. Bob Wicklein, Professor of Occupational Studies at the University of Georgia, plans to "design and develop a model summer engineering education institute focusing on the integration of engineering content with mathematics, science, and technology education" [48].

PROFESSIONAL ORGANIZATIONS

In 1998, the National Research Council (NRC) reported, "Today an individual faculty member who is interested in changing the way he or she teaches SMET has no central 'single point of contact' to begin a search for useful ideas" [31]. There are, however, many competent national and international organizations that offer great support in many aspects of engineering and technology education.

The International Technology Education Association (ITEA) serves more than 40,000 technology educators worldwide and "is the largest professional educational association, principal voice, and information clearinghouse devoted to enhancing technology education through experiences in our schools (K-12)" [22]. The ITEA (2000) published the K-12 *Standards for Technological Literacy: Content for the Study of Technology*, which is endorsed by William A. Wulf, President of the National Academy of Engineers. The ITEA's Technology for All Americans Project promotes technological literacy for all students. This organization also advocates elementary school technology education through the Technology for Children's Council, who publishes the journal *Technology and Children*. The Virginia Technology Education Association hosts the annual *Children's Engineering Conference*, and the Virginia Council for Elementary School Technology Education, publishes *The Children's Engineering Journal*.

The American Society for Engineering Education (ASEE) "is a non-profit member association, founded in 1893, dedicated to promoting and improving engineering and technology education" [2]. The Engineering Libraries Division of the ASEE, which can be found at http://www.englib.cornell.edu/eld/, provides information regarding meetings, programs and resources, publications, and discussion lists. Of ASEE's 43 Divisions and Constituent Committees, those included are Educational Research and Methods; Engineering Design Graphics; Engineering Technology; K-12 Outreach; and Manufacturing.

The Accreditation Board for Engineering and Technology (ABET) evaluates engineering, technology and applied science programs. Its vision is to "provide world leadership in assuring quality and in stimulating innovation in applied science, computing, engineering, and technology education" [1].

The Baltic States host an annual regional seminar on engineering education. "This seminar series has the on-going objective to bring together educators from the Baltic Region to continue and expand on debates about common problems and challenges in engineering and technology education, and to examine the need for innovation in engineering and technology education" [39]. Papers from the proceedings are peer reviewed before publishing and include topics such as "Innovation in engineering and technology education" and "Engineering and technology education in other countries" [39].

The Institute of Electrical and Electronics Engineers (IEEE) "is a non-profit, technical professional association of more than 360,000 individual members in 150 countries" [20]. This organization supports education through efforts like PEERS-Pre-College Educator/Engineer Resource Site (www.ieee.org/eab/peers), and the In-Service Teacher Program (www.ieee.org/eab/precollege/tispt/). IEEE pre-college education programs include *Technological Literacy Counts – Collaboration Between Education and Engineering Societies*.

The United Engineering Foundation (UEF) provided the IEEE and ASME International a grant to develop "joint outreach to engineers and educators about resources to support primary and secondary education" (UEF, n.d., Brochure). "ASME pre-college education services include workshops, teaching materials and partnership opportunities to help teachers and engineers to strengthen the math, science, engineering, and technology skills of young people and to assist them in becoming more aware of the role of engineering in their lives" (www.asme.org/education/precollege). The IEEE PEERS website (www.ieee.org/organizaitons/eab/precollege/peers/index.htm) was "developed to encourage collaboration and sharing between engineers and educators, and to provide resources for joint efforts to encourage students in the study of science, math, and technology."

The American Society of Mechanical Engineers (ASME) was founded in 1880 and currently serves 125,000 members across the globe (ASME, 2004, www.asme.org). In addition to the UEF project, the ASME provides a web site called *Classroom Resources Online* (www.asme.org/education/precollege). This organization has also taken a political stand for education in the development of a model bill for K-12 Science, Technology, Engineering, and Mathematics education.

The American Society of Mechanical Engineers Position Statement

In 2002, the American Society of Mechanical Engineers (ASME) began work on a model bill for K-12 STEM (Science, Technology, Engineering, and Mathematics) entitled, the *Science, Technology, Engineering, and Mathematics Education Competitiveness Act*. Legislative findings indicate,

> There appears to be a logical educational continuum within which the knowledge of science, technology, engineering, and mathematics is cumulative…. Yet the strands of middle and high school mathematics and science education do not weave seamlessly into college and university degree programs and the cumulative benefits of science, technology, engineering, and mathematics are less than they could be [3].

Participants of a state action program in Arkansas identified nineteen critical issues for the STEM community to level. While all are notable, these four seem especially relevant where the technology education/engineering education collaboration is concerned: Connecting and integrating strategies for collaboration; Developing enthusiastic, energetic, and skilled teachers; Fostering cooperation among the many stakeholders interested in improving STEM education; and Preparing a common language throughout the STEM community [3].

Other sections of this model bill provide goals and develop benchmarks for teachers, the educational infrastructure, school districts, the State Department of Education, partnerships, statewide organizations, research partnerships, and communities. Public education priorities include "providing students with hands-on, open-ended, real-world problem solving experiences which are linked to the curriculum" [3]. It is clear that the *Science, Technology, Engineering, and Mathematics Education Competitiveness Act* is student-centered and focuses on the increase in "numbers and quality of math, science, technology, and pre-engineering teachers" [3].

RECOMMENDATIONS FROM THE LITERATURE

Several authors have published reports that provide the rationale and recommendations for an engineering education and technology education collaboration. A "significant recommendation" of the National Research Committee on Science Education Standards and Assessment is that the concepts of engineering be taught in the technology education curriculum in the primary and secondary school level, grades K-12 [12]. In the current age of information technology, computer technology has become readily available, both in the home and school environments, to many K-12 students. However, Hendley recommends that students be provided "with experiences, self-images, and insights that cannot be readily obtained via a computer screen or even through an elegant virtual environment" [19]. This latter recommendation seems to be a call to expand an often limited definition of technology.

The Committee further recommends that this collaborative initiative include a major involvement and commitment of the engineering profession with technology education in the development and delivery of this new curricular effort. Historically, engineering has had limited involvement with education at the primary and secondary school levels [12]. Likewise, in the

ACT Policy Report, *Maintaining a Strong Engineering Workforce*, among many recommendations, Noeth, Cruce, and Harmston present three relevant to K-12 outreach:

- To nurture a broader interest in engineering, colleges and universities should**:** *in partnership with K-12 education leaders, expand their outreach activities at least into the middle school and include one or more institutional collaborations, and more innovative and experiential user-friendly outreach programs*;
- To ensure a well-prepared and diverse engineering workforce, professional engineering organizations should**:** *strive to provide a broad range of responsive pre-college, engineering resources, programs, and K-12 collaborations that include emerging specializations and interdisciplinary programs*; and
- To support the nation's present need for a strong and productive engineering workforce, and to successfully respond to future challenges to prepare a learning centered and adaptable engineering workforce, policy makers should**:** *bring together various constituencies (education, professional organizations, community agencies, private funding sources) to help address key issues including enhanced academic standards in science and technology across the K-12 system* [33].

These types of partnerships "are even more important in the new economy because it is apparent that public education alone cannot improve STEM education in a timely fashion" [3]. Nor can public education alone sustain these efforts long-term. The Committee on Undergraduate Science Education, Center for Science, Mathematics, and Engineering Education states, "We must maintain incentives for students to build and expand on their experiences through the undergraduate years. We must do this for all students, both those who do and those who do not aspire to be scientists, mathematicians, and engineers" [7].

Wulf states, "If any profession can meet a challenge head on, it is technology education" [50]. "Because of the hands-on, active nature of the technology/engineering environment, it is strongly recommended that it be taught in the middle and high school by teachers who are certified in technology education" [27]. "Mostly, and especially in the elementary grades, this content [the study of technology] will not be presented in stand-alone courses. Rather it will need to be infused in the lessons, lectures, and instructional materials already in place" [50]. Interdisciplinary topics should be introduced, "reducing the amount covered in order to allow for better learning" [43]. Additionally, "K-12 teachers [could act] as pedagogy experts to help college teachers learn new ways to teach" [10]. Improved pedagogy usually translates into "active student participation, a constructivist approach, the use of writing, and more projects. With increased use of technology comes a greater emphasis on visualization, the use of calculators, computers, and other equipment. Such technological tools, if properly utilized, can allow students to actively explore material and can extend learning opportunities to a wider variety of students [43].

Call for Action

"The sciences and mathematics are important to the understanding of the processes and meaning of technology. Integration [of science and mathematics] with the technology education curricula is vital" [23]. "In a very real sense, civilization itself depends on the evolution of technology so aptly delivered through engineering" [12]. Present social, cultural, environmental, and economic trends "make it essential that a much greater part of the population of active or productive age should be equipped with knowledge sufficient [to] develop useful skills but also to accept and integrate the existing innovation processes and discern important innovations of knowledge and technology [42].

Educating the technologists, engineers, mathematicians and scientists of tomorrow is of critical importance to the economy of this nation and public policy is needed to address effective education in these areas. As K-12 students gain knowledge and experience, "they are able to draw on other disciplines, especially mathematics and science, to understand and solve problems" [27]. Technology education is the school subject which can provide a fundamental education to all citizens in the future about the discipline of technology [12]. "Teachers who do not have a thorough understanding of the subject matter cannot transfer enthusiasm for that subject to their students" [43].

"Tremendous energy [is] needed to define roles, establish a common language, and build relationships to create and sustain" collaborations [16]. *Standards for Technological Literacy* can "provide a vision for incorporating the study of technology across the curriculum" [50]. Leaders in engineering education must work with leaders in technology education to forge new efforts to teach basic engineering concepts to all students. Much needs to be done to develop a long term "goal for what should be a direction and a vision for the intellectual content of the new 'Engineering & Technological' curriculum. Both professions will have to work together to get the support of business, industry, governmental agencies, and others for this new pioneering educational effort" [12]. "Possibly what sets the past 10 years of reform effort apart from all previous ones is the attempt to act systematically on educational systems through the creation of collaboratives that include state and local educational authorities, universities and colleges, and industry" [10].

Exciting teacher in-services must be created. “Meaningful, coherent and systemic innovation in SMET education requires the co-evolution of diverse institutions as well as new tools and materials” [47]. “While most see academia as having great inertia and ability to resist outside pressures for such major change, the dramatic postwar transition that created our research-centric institutions effectively demonstrates how quickly change can occur when conditions are favorable” [9].

Numerous efforts are underway to improve K-16 engineering education and many of those efforts warrant merit. Additionally, research studies have been conducted and strategic plans developed. However, in order to improve pedagogy and increase student achievement, action must be taken. Engineering's involvement is increasing in the K-12 environment, but could be furthered by collaboration with education. Collaboration between technology education and engineering education is a step in that direction.

There is a need to take existing collaboratives and cooperate, whether it is in one national organization or a special interest group under an existing organization. This calls for building a community for support and cooperation to exemplify best practices in technology education and engineering education. Opportunities to build this community abound through the National Science Foundation and the professional engineering and education organizations.

Using *Standards for Technological Literacy* as the foundation, course development and curriculum alignments ought to be considered for the benefit of all students. Post-secondary institutions must partner with K-12 education to implement articulation agreements allowing graduates to transition from one institution to another. Working together for the good of the students and the future of society will accomplish more than individual endeavors.

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