A Case for the Nationwide Inclusion of Engineering in the K-12 Curriculum via Technology Education

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Introduction

This paper resulted from discussions between a technology teacher educator and a colleague who has served in various education outreach roles with NASA. The basis of the paper was developed by the NASA director and two engineers, one serving with NASA and the other with the National Institute of Aerospace. That colleague is also a professor of mechanical and aerospace engineering at a major research university. The technology teacher educator read the original paper as published in the NASA Technical Report Server (NTRS) ntrs.nasa.gov/search.jsp (as document 20080018711) and realized that, though it addressed an audience of engineers, its implications for technology educators were obvious. As evident in the paper, the engineering community seeks a means to reach into the K-12 curriculum at the same time that leaders in technology education are promoting design and engineering in our curricula nationwide (Daugherty, 2005; Kelley and Kellam, 2009; Wicklein, 2006). Since we are both on the same page, it is important to cross-communicate—this revised version of the engineering paper with added implications for technology education provides support for current trends in our profession and shows how the linkages can best be implemented.

Some disclaimers are needed before proceeding. The reader will note that the perspective in much of the following discussion is that of the *engineer* as he or she describes their own role and differentiates it from the role of a scientist. Further, it is the engineering community of the United States. Hence, there are quotations and excerpts that may be perceived by some readers as extremist, parochial, exclusionary–perhaps even rudely so. Additionally, of the four letters in the oft-used acronym STEM, we in Technology Education frequently decry that the T is under stressed in our education community while the "S" and the "M" are emphasized. However, in this paper the perspective of the engineer makes much mention of "S", "T", and "E" while rarely mentioning the "M."

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Mathematics is rarely mentioned even in discussions about the differences and similarities among science, technology, and engineering. That is because, to the engineer, math is simply a way of life and a tool of the trade. Obviously, for both the engineer and the scientist, mathematics is central to every new discovery and application; math is at the heart of technology; and math will certainly be employed and reinforced in the new engineering-based courses in technology education. Further discussion of the importance of mathematics, however, is beyond the scope of this paper.

If a given cited reference or quotation in this paper seems to indicate that science and engineering are totally unrelated (using terms such as "always" or "exclusively"), that is one source's opinion or perspective, but the readers of the JTE are wise enough to cast that citation against others and find middle-ground norms. Still, this paper often presents genuine, though not always well accepted, perspectives that should be heard. This is done not to promote an "Americentric" or "engineering only" basis for technology education, but just so JTE readers will see the perspectives of the US engineering community without the "polishing" (read: smoothing out by abrasive action) of educators. That said, if nothing in this paper disturbs you a bit or seems overstressed, then you likely did not read carefully enough!

Engineering Education - Background

In a global, knowledge-based economy, technological innovation with its influence on competitiveness, long-term productivity, and improved quality of life is critical. One key factor to consider for the nation's primacy in technological innovation, national security, and its economic vitality is engineering education and practice. The leadership of the United States in technological innovation is challenged by the increase in research and development (R&D) by China and other nations. This accelerates the pace of discovery and application of new technologies, and demands the education of a 21st century technical (engineering) workforce. The US is experiencing a continued erosion of the engineering research infrastructure due to inadequate and lagging investment; declining interest of American students in science, technology, engineering, and mathematics (STEM); and an insufficient ability to attract and retain gifted engineering and science students from abroad at a time when foreign nationals constitute a large component of the US R&D workforce. (NAE, 2005). The nationwide inclusion of engineering in the K-12 curriculum through technology education could raise the interest of American students in STEM and in engineering careers.

Increasing acceptance of engineering as a discipline and profession in the United States has involved ongoing tensions and a search for a clearer identity; the same is true for engineering education. A college degree has not always been required to become an engineer because some believed that the skills needed could be better gained through experience rather than education. As Grayson (1993) pointed out, early, traditional universities viewed engineering as pragmatic and too utilitarian to be included as a discipline in higher education.

Westward expansion, the Morrill Act of 1862, and the industrial age led to new acceptance of engineering curricula in colleges. The twentieth century saw further expansion due to two world wars, Sputnik, and the rise of the United States as a world leader in technological innovation. Over the last 200 or so years, engineering has evolved into a recognized profession and a discipline with its own body of (engineering) knowledge. However, the current problem has more to do with identity and less to do with acceptance. Simply put, engineering is not (exclusively) applied science (though application of scientific principles is a part of what engineers do). Engineers are not scientists nor do they drive trains. Henry Petroski (2007) asks how engineering can be the most unrecognized occupation in the world when the results of what engineers do (make, produce) are so clearly obvious and important? It is very possible that the nationwide inclusion of engineering in the K-12 curriculum via technology education could help resolve the identity problem and also increase the interest of American students in engineering careers.

Science and Engineering

Science is concerned with the natural world and, as such, it is an introverted activity. Scientists study problems such as logical discrepancies, inconsistencies, or anomalous observations that lie beyond the existing intellectual framework. Scientists do their best work when investigating problems of their own selection in a manner of their own choosing (Amabile and Gryskiewicz, 1987). The output of science is knowledge and it is regarded by scientists essentially as a free good. The expectation within the scientific community is that knowledge will be made universally available through presentations at conferences and professional journals.

In opposition, engineering is an extroverted activity concerned with the designed world. It uses the design process of identifying a problem, designing a solution, and testing and improving the design to produce workable solutions and create the innovations that give us modern life with all its advances and conveniences. While engineering yields effective and workable solutions, it does not (often) pursue the why (Salomon, 1984).

Technology

Technology, the output of engineering, includes processes, products, systems, and services. Technological knowledge is not freely communicated and shared—there is usually a profit motive. “Technology, unlike science, often is not made universally available. Technology successfully functions only within a larger social environment that provides an effective combination of incentives and complementary inputs into the innovation process.” (Lindberg, Pinelli, and Batterson, 2008, p. 2) Technology is a process dominated by engineers rather than scientists (Landau and Rosenberg, 1986).

The Relationship between Science, Engineering, and Technology

Science and engineering play major roles in technological innovation through the production, transfer, and utilization of knowledge. In a capitalistic system, innovation relies on market forces and application of scientific and technical knowledge, along with human, technical, and financial resources, to create or improve products, processes, and services. Technical progress and economic growth depend upon innovation and economic growth fosters further technological innovation which creates jobs and raises the standard of living.

The assumption that technology grows out of or depends upon science suggests a linear path (or metamorphosis) from basic research (science) through applied science (with engineering as one aspect) to development (utilization or technology). This common notion may explain the use of the conventional phrase "scientists and engineers." In fact, science and technology (as developed by engineering) are somewhat interrelated in that advances in one may both depend upon and open the door for advances in the other. Differing aspects of this relationship can be examined in detail in Shapley and Roy (1985) and Allen (1977). "In short, a normal progression from science to technology does not exist, nor is there direct communication between science and technology. Rather, both are directly and indirectly supported by each other." (Lindberg, Pinelli, and Batterson, 2008, p. 3) No direct communication system among science, engineering, and technology exists other than the flawed one that exists in education.

Some recent researchers question the classic distinctions between science and technology as well as between scientists and engineers. They argue that if observations are made at either the actor level or the societal level, the distinctions between science and technology appear to fade (Latour, 1987). Through summarizing viewpoints of some theorists of technological studies, it appears that the structures of societies determine the technologies that will be developed (Law, 1987; Law and Callon, 1988; Rip, 1992; and Weingart, 1984). Rip (1992) asserted that "the dancing partnership of science and technology [is] a relation between activities oriented to different reference points and groups, rather than a matter of combining different cognitive-technical repertoires" (p. 257). Thus, science and technology, scientists and engineers, do many of the same activities but in different ways or with differing purposes.

The distinction between science and technology is further clouded when one looks closely at the varieties of actors and organizations that constitute technology.

> For example, in aerospace some engineers and scientists are working on methods to explore the edge of the universe and others on how to best design an aircraft . . . Some deal with very abstract ideas and others with difficult technological, economic, or management issues. Much research that attempts to understand the differences between science and engineering has examined what Constant (1980) termed radical science or technology. That is, much research focuses on changes in paradigms or fundamental ways of thinking about a phenomenon or artifact. For example, Constant examined the role of presumptive anomalies in technology to understand fundamental changes. His best example is the adoption of the jet engine. Little research focuses on the day-to-day activities of scientists and engineers where science and technology

> are maintained through routinized activities (Lindberg, Pinelli, and Batterson, 2008, p. 3).

Engineers and Scientists

The key difference between engineers and scientists can be defined on the basis of the primary goal of the output of their work–scientists produce knowledge (facts) and engineers produce designs, products, and processes (artifacts). There are other important differences such as the nature of their education and the type of work activities, but they point mainly to differences in their information-seeking behaviors and information needs.

Neither self-classification nor the analysis of tasks has accurately determined differences between engineers and scientists. Citro and Kalton (1989) found such errors when they attempted to describe differences based on analyses of tasks, job descriptions, education, and self-identification. Even using multiple indicators did not reduce the error. It is possible the increasing bureaucratization of these professions makes it more difficult to accurately differentiate them. Kintner (1993) used job classification, education, and job history as a means to identify engineers, but missed 15% of those who were actually doing engineering work.

The term “technoscience” to describe the relationship between engineering and science was employed by Latour (1987). Using a network actor perspective, he described daily activities of scientists and engineers. Results showed that:

> …personal success in technoscience did not depend primarily on how well engineers and scientists performed their jobs, but on how well they were able to recruit others into believing in the value of what they did. For those in technoscience, recruiting others included writing proposals, looking for funding for projects, doing research, and other activities that would not be considered either science or engineering. That is, success . . . does not depend so much on what is made (engineers) or on the development of new knowledge (scientists) but rather on how well the engineers and scientists are able to recruit others into the process of technoscience” (Lindberg, Pinelli, and Batterson, 2008, p. 4).

In short, when one examines engineers and scientists over the course of their careers, it may be difficult to distinguish between them. When making new products and knowledge, traditionally considered the activities of engineers and scientists (respectively), each group appears to behave quite differently; yet many of their activities, including management, are the same. The casual observer faced with these contradictions develops the misunderstanding that engineers are the same as scientists.

Differences between Engineers and Scientists

Despite changes in engineering and science over the past 20 years, Ritti (1971) found a marked contrast between the goals of engineers and scientists. Engineers in industry are concerned with meeting schedules, developing successful products, and helping the company expand. Although both engineers and scientists desire career advancement, for the engineer it is tied to activities within the organization while for the scientist it depends upon the reputation established outside the organization. Finally, publication of results and professional autonomy are highly valued goals of the Ph.D. scientist, but they are valued little by the baccalaureate engineer.

Blade (1963) noted that engineers and scientists differ in training, values, and methods of thought. Their individual creative processes and products differ with scientists most concerned with discovering and explaining nature while engineers use and exploit nature. Scientists search for theories and principles while engineers seek to develop and make things. To the scientist a result is sought for its own end. Engineers are engaged in solving problems for practical results while scientists create new unities of thought; engineers invent things and solve problems. Danielson (1960) found that engineers and scientists are fundamentally different in how they approach their work, the type and amount of supervision required, the recognition desired, and personality traits. In fact, Allen (1977) conjectured that the type of person who is attracted to engineering is fundamentally different from one whose career is in science:

> Perhaps the single most important difference between the two is the level of education. Engineers are generally educated to the baccalaureate level; some have a master's degree. The scientist is usually assumed to have a doctorate. The long, complex process of academic socialization involved in obtaining the Ph.D. is bound to result in persons who differ considerably in their life views. (1977, p. 5)

In a later work, Allen (1984) concluded that the differences in values and attitudes toward work are reflected in an individual's behavior and in their use and production of knowledge.

Much of the research on differences between engineers and scientists is aging and fails to consider the impact of changes in post-World War II engineering curricula and the Sputnik era to meet military and industrial challenges (Grayson, 1993). The Grinter Report (1955), prepared by a committee of the American Society for Engineering Education (ASEE), urged inclusion of more science and liberal arts in engineering education. This transformed engineering education in two decades from "hands-on" training to a more theoretical perspective resembling other academic disciplines such as the sciences. Grayson (1993) calls the period from World War II through 1970 the "scientific" period. Since the 1960s the distinction between the training of engineers and scientists has blurred. Likewise, the types of work that they do in large bureaucratic organizations makes it increasingly difficult to differentiate them by title alone.

> Engineering can be defined as the creation or improvement of technology. As such, it clearly encompasses both intellectual and physical tasks (i.e., both knowing and doing). Engineering . . . is a social activity in that it often involves teamwork, as individuals are required to coordinate and integrate their work (Lindberg, Pinelli, and Batterson, 2008, p. 5).

They continue to explain that "the production of the final product depends on the ability to maintain successful social relationships (e.g., negotiate with vendors, maintain smooth personal relations among members of a work group). Membership in a community is important for the effective functioning of . . . engineers." (p. 5). Engineers work in an embedded set of contextual relationships while scientists often conduct activities with only a vague reference to others doing similar work.

Similarities between Engineers and Scientists

At times engineers behave very similarly to scientists and adopt scientific methods to generate knowledge. Ritti (1971) asserted that engineering work includes scientific experimentation, mathematical analysis, design, drafting, building and testing prototypes, technical writing, marketing, and project management. More recently Kemper (1990) noted that typical engineers define problems, develop new ideas, produce designs, solve problems, manage the work of others, produce reports, perform calculations, and conduct experiments. Florman (1987) described engineering work as encompassing both theory and empiricism while Ziman (1984) concluded "technological development itself has become 'scientific'. It is no longer satisfactory, in the design of a new automobile, say, to rely on rule of thumb, cut and fit, or simple trial and error. Data are collected, phenomena are observed, hypotheses are proposed, and theories are tested in the true spirit of the hypothetico-deductive method (p. 130)."

In 1980, Constant described the similarities between engineering and science in his history of the development of the jet engine. He used a "variation-retention" model to describe how engineers and scientists create technological change. Change in technology results from random variation and selective retention. Technological conjecture may occur as a result of knowledge gained from scientific theory or engineering practice. It yields potential variations to existing technologies. In the case of the turbojet, technological conjecture was based on engineers' knowledge of scientific theories. In contrast, when writing, scientists often describe their methods as following the hypothetico-deductive method. However, in their daily research activities, they often use methods similar to those of engineers such as the variation-retention method.

Engineering in the K-12 Curriculum through Technology Education

In recent times one often hears that within STEM education, the "E" is silent. In K-12 education, engineering is partially represented via science and mathematics, so it would be incorrect to say it is totally absent. The point is that both science and mathematics have supporting national standards and career information, and both exist nationwide in grades K-12, yet engineering does not have a significant presence at this level of education. At the same time, engineering was included in the National Research Council's (1996) *National Science Education Standards*. The problem is that it is represented as applied science rather than as engineering. The same is true for science standards in many states. On a related note, the International Technology Education

Association (ITEA, 2000) has promulgated the *National Standards for Technological Literacy*. Likewise, the National Council of Teachers of Mathematics (NCTM, 2000) published the *Principles and Standards for School Mathematics,* The American Association for the Advancement of Science (AAAS) published *Benchmarks for Science Literacy* (1993) and *Science for All Americans* (1989). Two chapters of this publication – "The Nature of Technology" and "The Designed World" – refer to the "human control of technology" which is tacit acknowledgement of engineering. The ITEA sources also use the same terminology freely. Within K-12 STEM education, national standards exist for the "S", "T", and "M" but not the "E" except as it is represented piecemeal in those for "S", "T", and "M."

Engineering is not entirely absent from grades K-12. Massachusetts, for example, has developed and implemented a K-12 engineering curriculum complete with corresponding standards:
http://www.doe.mass.edu/framework/scitech/2001
Several states appear to be moving in this same direction and there are three nationally available K-12 engineering programs – Ford Motor Company's *Partnership for Advanced Study (PAS)*; *Project Lead the Way*; and Texas Instrument's *Infinity Project*. Ford's PAS (http://www.fordpas.org/about/) program is inquiry- and project-based, academically rigorous, and interdisciplinary. The program provides students with content knowledge and skills necessary for future success in business, economics, engineering, and technology.

Project Lead the Way (PLTW) (http://www.pltw.org/about/about-us.html) was created in New York state to fill a curriculum gap for high schools. PLTW is a not-for-profit organization promoting engineering courses for the middle grades and high school grades in partnerships with public schools, higher education institutions, and the private sector to increase the quantity and quality of engineers and engineering technology graduates.

The Infinity Project (http://www.infinity-project.org) was developed by the Institute for Engineering Education and Texas Instruments, working in partnership with the U.S. Department of Education and the National Science Foundation, to help fill the need for U.S. engineering graduates by encouraging more young students to pursue engineering careers.

The common reasons for not offering K-12 engineering are familiar: no room in the curriculum, lack of funds, and difficulty finding qualified teachers. A common solution is to include engineering concepts in existing courses. It is our contention, however, that "engineering is a stand alone discipline with an established body of knowledge that deserves to either 'stand or fall' on its own merits . . . the value it adds to K-12 education and to the teaching and learning of STEM, and the role it plays in helping to create a technologically literate citizenry and society." (Lindberg, Pinelli, and Batterson, 2008, p. 6, representing the engineering community) Within this context, three reasons for nationwide inclusion of engineering in the K-12 curriculum are offered below.

1. To Support the Engineering Pipeline

The United States faces a critical shortage of engineers in the decades ahead. The NSF estimated that the shortage of engineers in the United States will reach 70,000 by the year 2010. Is there really an engineering shortage? It depends on who is telling the story. One thing is certain: It is difficult to pick up a magazine or paper, or look at a news and commentary website, without seeing knowledgeable people bemoaning and debating the “engineering shortage.” Though they may not pass the scrutiny to stand as refereed evidence, here are some factoids gleaned from the Web as by Lindberg, Pinelli, and Batterson (2008, p. 6).

- Fewer than 15 percent of all current high school graduates have the math and science background necessary to successfully pursue an engineering degree.
- More than 85% of students today aren't considering careers in engineering.
- Only two of every 100 high school graduates go on to earn engineering degrees.
- Only five of every 1,000 female or minority graduates become engineers.
- Europe produces nearly three times as many engineering graduates as the United States. Asia produces almost five times as many.
- More than half of all U.S. engineers are near retirement age.
- Nationwide, engineering enrollment and retention is down.
- Engineering has a perception problem that discourages students from pursuing the profession.
- K-12 schools lack an engineering tradition.
- American students are lazy and engineering is boring; the smart kids choose more exciting majors.

If there is a shortage, steps need to be taken now to introduce more middle and high school students to engineers and engineering careers. We must make them aware of the importance, challenge, and excitement of engineering and make certain that they have reliable information about the courses needed to prepare for college. Adding engineering to the K-12 curriculum could serve as a means of closing the gap. Lindberg, Pinelli, and Batterson (2008) identified learning objectives for K-12 engineering from the literature:

- Understand why and how humans design, engineer, and innovate to meet our needs.
- Develop critical thinking and analytical skills by applying the design process.
- Use, manage, and evaluate designs and technology-based systems.
- Understand the relationship between STEM concepts and STEM courses.
- Learn to communicate engineering and technical content individually and as part of a team.
- Understand the historical implications and significance of engineering and its relationship to societal evolution.

- Become aware of and appreciate engineering as a career path. (p. 7)

2. To Enhance and Enrich the Teaching and Learning of STEM

Engineering should be viewed as curriculum only when it directly supports the engineering career pipeline. Engineering does, however, complement the learning objectives of other subjects, particularly science, technology, and mathematics. Some understanding of engineering is an important attribute of both scientific and technological literacy. The problem solving orientation and teamwork characteristics of engineering, essential 21st century workforce skills, directly support the overall goals of elementary and secondary schools. Many science and mathematics educators believe that engineering, especially the engineering design process, provides the context for valuable application opportunities and motivation for students.

Engineering can reinforce scientific inquiry and the scientific method. It can provide clear illustrations to help students understand scientific and mathematical concepts. In recent years, the NSF has funded curriculum projects in which engineering was used as methodology for demonstrating the interdisciplinary nature of mathematics, science, and technology. Some of these projects were university-developed and yielded engineering-based learning modules and professional development activities for K-12 teachers.

Lindberg, Pinelli, and Batterson (2008) identified the following valuable outcomes of using engineering to enhance and enrich the teaching and learning of STEM in K-12:

- Develops problem solving and critical thinking and skills.
- Develops reasoning, estimating, and analytical skills.
- Illustrates the relationship(s) between “higher level” math and science concepts and the “real world”.
- Demonstrates the value of teamwork, cooperation, and collaboration.
- Builds language arts and communication skills.
- Increases scientific and technological literacy.
- Nurtures creativity, ingenuity, and innovation.
- Fosters organizational, planning, and time management skills. (p. 7)

Despite the apparent benefits, a number of challenges still exist to using engineering to enhance and enrich STEM learning in K-12. One challenge is teacher certification and professional development. Another is the overcrowded curriculum, mentioned earlier and this is aggravated by “high stakes” testing. Without fundamental knowledge, curriculum developers who are not themselves engineers, and engineers who have no pedagogical knowledge, may not be able to make the “content connections” between engineering and other subjects. They may have difficulty establishing appropriate learning outcomes and effective instructional strategies integrating engineering concepts. Likewise, policy makers have little or incorrect information on which to base decisions concerning student achievement in STEM or the potential value of using engineering as "methodology" to teach other subjects.

3. To Create a Technologically Literate Citizenry and Society

Though there are several competing definitions of technological literacy, most have similar elements. The authors define technological literacy as "knowledge about what technology is, how it works, what purposes it can serve, and how it can be used efficiently and effectively to achieve specific goals" (Lindberg, Pinelli, and Batterson, 2008, p. 8). Conventional wisdom assumes we live in a world that is increasingly dependent on technology; technological literacy is essential for job readiness, citizenry, and life skills; it is vital that Americans be technologically literate; and to be technologically literate requires understanding the nature of science and technology. From a societal standpoint, a technologically literate citizenry (especially decision makers and public policymakers) improves the likelihood that decisions about the use of technology will be made rationally and responsibly. Sadly, too many Americans are poorly prepared to think critically about today's important technological issues. Much is known about people's opinions or attitudes about technology but very little about how much they understand it. Some educators hold the opinion that students should develop technological literacy skills in the context of learning and solving problems related to academic content. An engineering-based curriculum is well suited to help meet these needs. Students are generally considered to be technologically literate if they can:

- Demonstrate a sound conceptual understanding of the nature of technology systems and view themselves as proficient users of these systems.
- Understand and model positive, ethical use of technology in both social and personal contexts.
- Use a variety of technology tools in effective ways to increase creative productivity.
- Use communication tools to reach out to the world beyond the classroom and communicate ideas in powerful ways.
- Use technology effectively to access, evaluate, process and synthesize information from a variety of sources.
- Use technology to identify and solve complex problems in real-world contexts. (Lindberg, Pinelli, and Batterson, 2008, p. 8)

The programs and publications of the National Center for Technological Literacy (http://www.mos.org/nctl/), the publication of the *Standards for Technological Literacy*, (ITEA, 2000) (http://www.iteaconnect.org/) and the publication of *Technically Speaking*: *Why All Americans Need to Know More About Technology* (Pearson and Young, 2002) (http://www.nap.edu/catalog) in combination, created new impetus for technology educators to adopt an engineering approach to teaching. The ITEA standards suggest that students should know and appreciate engineering, understand the role that design and engineering play in the creation of technology, and be able to carry out engineering design activities (Meade and Dugger, 2004).

Toward Nationwide Inclusion of Engineering via Technology Education

There is concern that the current curricula, instructional strategies, and emphasis on rote learning (driven by end of course standardized testing) will not produce the higher order thinking and analytical skills needed in the 21st Century workforce. Perhaps new methods of teaching, new and innovative (cognitive-based) instructional strategies (employing student-centered learning), and new approaches to teaching and learning will help. We are passionate in our belief that the inclusion of engineering in the K-12 curriculum, via technology education, provides the opportunity to make these changes. How can it happen? The following are certainly needed:

- Commitment from the engineering community.
- Leadership in the form of a "champion."
- Identification and engagement of the stakeholders.
- Implementation of a series of strategically crafted alliances, collaborations, and partnerships.
- More programs for producing teachers.

Lindberg, Pinelli, and Batterson (2008) asserted that major responsibility for securing the political and economic capital to develop and implement K-12 engineering curricula rests with engineering school deans in collaboration with educators—especially technology educators. At the state level, the deans are best suited and positioned to assume a leading role in this effort and to develop the coalition needed to receive the approval of their respective state legislatures. The development of national engineering education standards is crucial. Perhaps the National Academy of Engineering in cooperation with the American Society of Engineering Education (ASEE), the International Technology Education Association (ITEA), and a coalition of professional engineering societies are best suited to accomplish this task.

A Novel Perspective for Engineering in Technology Education

Despite this clearly portrayed case for the inclusion of engineering in technology education and the rush by many professionals to promote it, one issue has received too little attention. That issue is the elitist nature of many proposed courses that would exclude many students. In the recent dialog concerning a potential shift in the curriculum of technology education towards engineering, most of the engineering-based courses have a mathematics or mathematics and physics pre-requisite. These pre- or co-requisites deny entry into the courses for students in the "average" and "below average" academic groups. Technology education still has a responsibility to meet the needs of those students who are not at the top academically. A possible means to meet the needs of some of these students while advancing engineering in the TE curriculum is to do exactly what engineering teams do in real life (Wicklein, Smith, and Kim, 2009). Engineering teams in large organizations generally include some members who execute the plans and build the prototypes. Rarely are these the same folks who set up the mathematical algorithms and solve the calculus problems. Additional skills and talents beyond mathematical adeptness that are needed in a successful engineering team include:

- Communication of ideas by written, graphic, and oral means.
- Construction and testing of mock-ups and prototypes
- Understanding of how to make things
- A "feel" for how strong materials are in building prototypes
- Creative brainstorming with multiple viewpoints represented.

A truly successful engineering design team rarely is one-dimensional consisting of stereotypical "math geniuses." Rather, it is more likely to be a large tent under which many and diverse beings can gather and work together comfortably to solve a problem. Sometimes in real life it is the technician who finally solves the thorny problem that is blocking the success of a venture or project. Technology education must insure that its engineering-based courses do not succumb to the temptation of becoming elitist safe harbors for only the top students—there are already plenty of those in every school in the nation. Technology education must maintain its democratic and inclusive ability to meet the needs of all students.

A Possible Approach to Consider

There must be some means of reaching all students through an engineering-based TE curriculum. Previously in this paper it was noted that in the early days of classic education, engineering was considered too practical in nature to be worthy of academic status. Now it seems that it is too academic in nature for some students to enjoy or even participate. What follows are two approaches for consideration. The details are not provided as the TE and engineering communities need to collaboratively develop them. Both approaches involve teams or design groups of future engineers and future technicians working together:

1. All levels of students enroll in the same course but performance expectations differ such that the "engineers" in the groups receive some form of honors credits, or
2. Two courses (designed for different levels of students) meet simultaneously in the same lab and work in teams to solve engineering problems.

Both schemas allow students of all academic levels to learn from each other and develop an appreciation of each other as they work closely in the engineering teams. Both approaches mirror what happens in large-scale engineering teams.

In contrast, the approach taken by many current engineering programs operating under the technology education umbrella may be leading potential engineering students into concluding that their careers will involve mainly the hands-on construction of prototypes, models, or products since “technicians” have not been identified within the design teams in their class and consequently the “engineer” members do the building themselves. In the real world, except in very small companies, the two roles are played by very different sorts of people with vastly differing educational preparation, knowledge, and skills. Under this scenario, there is room for both groups to work together.

The courses most certainly will integrate a variety of subjects, including communication, technology, engineering, mathematics, science, and the arts. A key component of such an approach, of course, is the provision of high quality, directly pertinent professional development (see Merrill, Custer, Daugherty, Westrick, and Zeng, 2008). Responsibility for this will fall on teacher educators in technology education working in collaboration with colleagues in engineering.

Conclusions and a Challenge

Whatever approach is used, it is imperative that engineering be included in the K-12 school curriculum, both as a discipline and as a source of enrichment and context for teaching other subjects. There is no better place for this to occur than in technology education. The authors hope that the perspective from the community of engineers shared in this paper will lend support to those leaders in technology education who are working to include engineering, resulting in the development of a fuller context for their arguments and providing some useful ideas as to how engineering can be included without eliminating the positive outcomes of contemporary technology education and the industrial arts of yesteryear from which it evolved. Wright, Washer, Watkins, and Scott (2008) clearly pointed out that some TE teachers view their courses as college preparatory while others do not. There should be a way in our discipline to reach the needs of all students through working together in goal-oriented groups. Kelley (2008) noted the importance of the groups having diversity in problem solving approaches. We contend that the groups should be diverse in all ways that society is diverse, including academic ability levels and interests.

New technology education courses employing multi-dimensional engineering design teams can better portray the engineering profession, aid in recruitment of future engineers, and meet the needs of a diverse array of tomorrow’s students. They will also better represent the ITEA standards, even for those students who will not pursue a career in engineering. Creative engineering problems in a school environment can provide a context for problem solving, attaining technological literacy, and developing 21st century skills. We challenge our colleagues to develop new approaches incorporating the ideas presented to develop engineering-based technology education courses that meet the needs of all students while helping supply the engineers for the future.

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