Sense and Sensibility: The Case for the Nationwide Inclusion of Engineering In the K-12 Curriculum

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Abstract – The competitive status of the United States is inextricably linked to innovation just as innovation is inseparable from science, technology, engineering, and mathematics. To stay competitive in innovation requires that the United States produce a 21st century workforce complete with requisite education, training, skills, and motivation. If we accept a priori that science, technology, engineering, and mathematics education and are crucial to competitiveness and innovation and that, in terms of innovation, mathematics, science, and engineering are interdependent, why are mathematics and science uniformly ubiquitous in the K-12 curriculum while engineering is conspicuously absent? We are passionate in our belief that the uniform addition of engineering to the K-12 curriculum will help ensure that the nation has "the right" 21st Century workforce. Furthermore, we believe that a nationwide effort, led by a coalition of engineering academics, practitioners, and societies is required to turn this goal into reality. However, accomplishing this goal necessitates, as we are reminded by the title of Jane Austen's timeless novel, Sense and Sensibility, a workable solution that seeks the "middle ground" between passion and reason. We begin our paper by making two essential points: Engineers are not scientists. Engineering exists separate from science, has its own specialized knowledge community apart from science, and it is largely responsible for many of the most significant advancements and improvements in the quality of our life. Our workable solution requires that K-12 education, nationwide, accommodate the inclusion of engineering as a stand alone curriculum and we offer three reasons to support our position: (1) workforce development, (2) stimulating interest in STEM (science, technology, engineering, and mathematics) courses and careers, and (3) creating a technologically literate society. We conclude with some thoughts on how this important goal can be accomplished.

Keywords: K-12, Engineering, Competitiveness, Workforce, Curriculum

INTRODUCTION

Leadership in innovation is essential to U.S. economic and national security. In an increasingly global, knowledge-based economy, technological innovation – the transformation of new knowledge into products, processes, and services of value to society – is critical to competitiveness, long-term productivity growth, and an improved quality of life. The nation's primacy in technological innovation, its national security, and its economic vitality depend on a wide array of factors, one of which is engineering education and practice. United States leadership in technological innovation, within an increasingly competitive global economy, is being severely tested. China and other nations are increasing their investment in research and development (R&D) – which accelerates the pace of discovery and application of new technologies, and in the education of a technical (engineering) workforce. U.S. leadership is facing a growing imbalance in federal research funding between the engineering and physical sciences and biomedical and life sciences; increased emphasis on short-term applied R&D in industry and government-funded research at the expense of fundamental long-term research; 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 growing uncertainty about the ability of the United States to attract and retain gifted

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engineering and science students from abroad at a time when foreign nationals constitute a large and productive component of the U.S. R&D workforce. [NAE, 22] It is very possible, we contend, that the nationwide inclusion of engineering in the K-12 curriculum could raise the interest of American students in STEM and in engineering careers.

The rise and acceptance of engineering as a discipline and a profession in the United States has been characterized by progressive tensions and the search for identity. (Perhaps the same can also be said for engineering education.) Early on, one could become an engineer without going to school let alone attaining a college degree for it was believed that the skills required of an engineer could be better acquired through experience than through formal education. As Grayson [11] points out, “the then traditional universities viewed engineering as too pragmatic and utilitarian for higher education.” Over time and with westward expansion, the passage of the Morill Act of 1862, the advent of the industrial age, two world wars, Sputnik, and the rise of the United States as a world leader in technological innovation, all that changed. During that 200 plus years, engineering has evolved into an acceptable profession, a discipline with its own body of (engineering) knowledge, an essential ingredient of technological innovation and technical progress. The problem today has (perhaps) more to do with identity and less to do with acceptance. Engineering is not applied science. Engineers are not scientists and they do much more than drive trains. Paraphrasing Henry Petroski [26], how can engineering be the most unrecognized occupation in the world when the results of what engineers do (make, produce) are among the most recognized and revered wonders on Earth? It is very possible, we contend, that the nationwide inclusion of engineering in the K-12 curriculum could help resolve the identity problem and also increase the interest of American students in engineering careers.

SCIENCE AND ENGINEERING

Science is an introverted activity that is concerned with the natural world. Scientists study problems that are usually generated internally by logical discrepancies or inconsistencies or by anomalous observations that cannot be accounted for within the present intellectual framework. Indeed, scientists are said to do their best work when investigating problems of their own selection and in a manner of their own choosing [Amabile, 3]. The output of science is knowledge that 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 society meetings and publication in scholarly and professional journals.

Engineering, on the other hand, is an extroverted activity that is concerned with the designed world; it uses the design process – identifying a problem, designing a solution, testing and improving the design – to produce workable solutions for our nation’s most pressing problems and to create the innovations that give us modern life with all its advances and conveniences. When engineering yields solutions that are workable and effective, it does not pursue the why [Salomon, 29]. Technology, the output of engineering, is frequently a process, product, system, or service. Technological knowledge is not freely communicated. 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. Technology is a process dominated by engineers rather than scientists [Landau, 16].

The Relationship between Science and Engineering

Science and engineering play a major role in technological innovation through the production, transfer, and utilization of knowledge. The process of innovation, applied within a capitalist system, relies primarily on market forces and the use of (and advances in) scientific and technical knowledge, coupled with human, technical, and financial resources, to create new (or improve existing) products, processes, and services. Without both kinds of knowledge, there is no innovation. Innovation begets technical progress and economic growth, and economic growth fosters technological innovation, creates jobs, and generally raises the standard of living. Although technical progress and economic growth and competitiveness are inextricably linked to advances in science and technology, the relationship among these variables is often sometimes stochastic. The general assumption that technology grows out of or depends upon science for its development, suggests that the metamorphosis from science to technology is a continuous process (or follows a linear path) from basic research (science) through applied science (engineering) to development (utilization). The prevalence of this mindset may help explain the use of the conventional phrase “scientists and engineers”.

Several scholars claim that (1) most technological advances are derived immediately from the technology that preceded them, not from science or applied science and (2) that science and technology progress independently of one another. Shapley and Roy [30], for example, assert that technology builds upon its own prior developments and advances in a manner independent of any link with the current scientific frontier and often without any necessity for an understanding of the basic science underlying it. 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. Allen's [1] classic study of the transfer of technology and the dissemination of technological information in R&D organizations found little evidence to support the relationship between science and technology as a continuous relationship. Allen concluded that the relationship between science and engineering is best described as a series of interactions that are based on need rather than on a normal progression. According to Allen, the results of science do progress to technology in the sense that some sciences such as physics are more closely connected to technologies such as electronics, but overall, a wide variation exists between science and technology. A direct communication system between science and technology does not exist. The most direct communication between science and engineering takes place through the process of education.

In recent years, several researchers have questioned the classic distinctions between science and technology and between scientists and engineers. Many current theories of science and technology (e.g., Latour [17]) argue that if researchers make their observations at either the actor level or the societal level, the distinctions between science and technology appear to fade. Some theorists of technology studies believe that the structures of societies determine the technologies that will be developed (Law [19] , Weingart, [31]). Law and Callon [20], for example, argue that engineers are social activists who design societies and social institutions to fit technologies (p. 284). Rip [27] argues that the perspective of the researcher indicates the interpretation of where to place activities or actors in science or technology. He further argues 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). That is, science and technology, scientists and engineers do many of the same activities but in different ways.

However, 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 for passenger comfort. 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 [8] 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 [8] 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.

Engineers and Scientists

For our purposes, we define the essential difference between engineers and scientists based on the primary goal of the output of their work – scientists produce knowledge (facts) and engineers produce knowledge and designs, products, and processes (artifacts). Engineers and scientists exhibit many other important differences in education, technical discipline, and type of work activities. These differences point to differences in their information-seeking behaviors and information needs. In this section, we describe many of the differences, starting with differences in characteristics and proceeding to differences in their outputs.

Differences between engineers and scientists are difficult to determine from either self-classification or the analysis of their tasks. Citro and Kalton [7] (pp. 26-56) describe differences based on analyses of tasks, job descriptions, education, and self-identification. Their analysis indicated that even using multiple indicators did not reduce the error in classifications into engineering and science. We suspect that the increasing bureaucratization of these professions makes it more difficult to accurately differentiate them. Kintner [15] attempted to determine who was an engineer based on the job classification, education, and job history. The results of a multivariate statistical procedure indicated that at least 15% of those who were doing engineering work would be missed using various classification schemes.

Latour [17] used the term “technoscience” to describe the relationship between engineering and science. Using a network actor perspective, he described the daily activities of both scientists and engineers. He found 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 in engineering and science 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.

When one examines engineers and scientists over the course of their careers, it becomes increasingly difficult to distinguish them. When each does those activities that we traditionally consider the activities of engineers and scientists (making new products and new knowledge, respectively), each group appears to behave quite differently. Yet many of their activities, such as management, are the same. Contradictions based on the various views of the differences between the groups contribute to the misunderstanding that engineers are the same as scientists.

Differences between Engineers and Scientists

Despite the changes in engineering and science over the past 20 years, many differences noted by Ritti [28] still distinguish the two groups. In his study of engineers in industry, Ritti [28] found marked contrast between the goals of engineers and scientists—(a) the goals of engineers in industry are very much in line with meeting schedules, developing products that will be successful in the marketplace, and helping the company expand its activities; (b) although both engineers and scientists desire career advancement or development, advancement for the engineer is tied to activities within the organization, whereas advancement for the scientist is dependent upon the reputation established outside the organization; and (c) whereas publication of results and professional autonomy are clearly valued goals of the Ph.D. scientist, they are clearly the least valued goals of the baccalaureate engineer (Ritti [28] cited in Allen [1], p. 5).

Blade [6] states that engineers and scientists differ in training, values, and methods of thought. In particular, in their individual creative processes and in their creative products—(a) scientists are concerned with discovering and explaining nature; engineers use and exploit nature; (b) scientists search for theories and principles; engineers seek to develop and make things; (c) scientists seek a result for its own end; engineers are engaged in solving a problem for the practical operating results; and (d) scientists create new unities of thought; engineers invent things and solve problems. Danielson [9] found that engineers and scientists are fundamentally different in terms of how they approach their jobs, the type and amount of supervision they require, the type of recognition they desire, and their personality traits.

Allen [1] stated that the type of person who is attracted to a career in engineering is fundamentally different from the type of person who pursues a career as a scientist. He wrote that “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.” (p. 5) According to Allen [2], these differences in values and attitudes toward work will almost certainly be reflected in an individual’s behavior, especially in the use and production of knowledge.

Unfortunately, much of the research on the differences between engineers and scientists is aging and does not reflect the impact of changes in post-World War II engineering curricula. During World War II and throughout the era of Sputnik, government and industry leaders recognized that engineering training in the U.S. was not adequate to meet military and industrial challenges [Grayson, 11]. The Grinter Report [12], prepared by a committee of the American Society for Engineering Education (ASEE), urged the inclusion of more science and liberal arts into engineering education. This 1955 report transformed engineering education over the subsequent two decades from “hands-on” training to a more theoretical perspective resembling other types of academic disciplines, particularly the sciences. In his history of engineering education in the U.S., Grayson [11] terms the period from World War II through 1970 the “scientific” period. Engineering education since the 1960s has tended to blur the distinction between the training of engineers and scientists. In addition, the types of work that they do in the large bureaucratic organizations that employ them makes it increasingly difficult to differentiate them by title alone. From a research perspective, it is difficult to observe a clear difference between engineers and scientists in many settings.

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 work is fundamentally both a social and a technical activity. It is a social activity in that it often involves teamwork, as individuals are required to coordinate and integrate their work. It is also a social activity in 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 current engineering and engineers. Engineers do their work in an embedded set of contextual relationships. Science, on the other hand, allows scientists to conduct their daily activities with only a vague reference to others doing similar work.

Similarities between Engineers and Scientists

A number of writers note that engineers behave very similarly to scientists. At times, they adopt the methods used by scientists to generate knowledge. For example, according to Ritti [28], engineering work consists of scientific experimentation, mathematical analysis, design and drafting, building and testing of prototypes, technical writing, marketing, and project management. Kemper [14], too, noted that the typical engineer is likely to define problems, come up with new ideas, produce designs, solve problems, manage the work of others, produce reports, perform calculations, and conduct experiments. Florman [10] described engineering work as encompassing both theory and empiricism. Ziman [32] wrote that "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)."

Constant [8] also described the similarities between engineering and science in his detailed history of the origin of the modern jet engine. He defined 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, which can occur as a result of knowledge gained from scientific theory or engineering practice, yields potential variations to existing technologies. For example, in the case of the turbojet revolution, technological conjecture was based on engineers' knowledge of scientific theories. In contrast, in their writings, scientists usually describe their methods as following the hypothetico-deductive method. However, in many of their daily research activities, they use methods similar to those used by engineers—particularly the variation-retention method.

THE CASE FOR THE NATIONWIDE INCLUSION OF ENGINEERING IN THE K-12 CURRICULUM

A colleague recently told us that within STEM education, the "E" is silent. In terms of K-12 education, our colleague may have a point. While engineering is often conflated with science and mathematics, it would be incorrect to say that engineering is totally absent from the K-12 curriculum. The point our colleague was attempting to make is this: Science, (and mathematics) with its supporting national standards and career information, exists nationwide in grades K-12, yet engineering does not. In that context, our colleague is correct. It would also be incorrect to say that engineering is absent from the National Research Council's [24] *National Science Education Standards*. The problem, according to our colleague, is that it is represented as applied science, not as engineering. (The same is purported to also be true for a majority of state science standards.) On a related note, the International Technology Education Association (ITEA) [13] has promulgated the *National Standards for Technological Literacy* and the National Council of Teachers of Mathematics (NCTM) [23] published the *Principles and Standards for School Mathematics*. The American Association for the Advancement of Science (AAAS) published *Benchmarks for Science Literacy* [4] *and Science for All Americans* [5]. 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. Within K-12 STEM education, national standards exist for the "S", "T", and "M" but not the "E".

Nationwide, engineering is not totally absent from grades K-12. Indeed, progress is being made. To date, Massachusetts http://www.doe.mass.edu/framework/scitech/2001 is the only state in the U.S. that has developed and implemented a K-12 engineering curriculum complete with corresponding state standards of learning; now several states appear to be moving in that direction. Additionally, there are three (3) 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 an inquiry- and project-based, academically rigorous, interdisciplinary curriculum and program that provides students with content knowledge and skills necessary for future success in such areas as 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 in engineering for high schools. PLTW is now a not-for-profit organization that promotes engineering courses for middle grades and high school students. PLTW, Inc. forms 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 close the gap between the number of U.S. engineering graduates and the large need for high-quality engineering graduates in the near future by encouraging more young students to pursue engineering careers.

The reasons given most often by school officials for not offering K-12 engineering have a familiar ring. Chief among them are: (1) there is no room in the curriculum, (2) we would have to drop something to add engineering, (3) we lack the funds, (4) where in the world would we find people to teach engineering, and (5) if the inclusion of engineering is that important, why not offer it within existing courses such as physics or technology education? The response to this last reason is fairly straight forward: Engineering is a stand alone discipline with an established body of knowledge that deserves to either "stand or fall" on its own merits relative to its role in fostering technical innovation and technical progress, 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. Within this context, we offer three reasons for nationwide inclusion of engineering in the K-12 curriculum.

Supporting the Engineering Pipeline

Does the United States face a critical shortage of engineers in the decades ahead? According to an NSF estimate, 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 web site, without seeing knowledgeable people bemoaning and debating the "engineering shortage."

Here are some factoids we gleaned from the Web.

- Fewer than 15 percent of all current high school graduates have the math and science background necessary to successfully pursue an engineering degree.
- 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 approaching 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 (there have been engineering shortages before), steps need to be taken now to encourage more young students to pursue engineering careers. We need to introduce more middle and high school students to engineers and engineering careers; make them aware of the importance, challenge, and excitement of engineering; and make certain that they have reliable information about the courses they need to take to prepare themselves for college. Adding engineering to the K-12 curriculum could serve as a means of closing the gap between the number of engineering graduates currently produced in the United States and the need for high quality engineering graduates in the near future. With respect to learning objectives and K-12 engineering, we extracted the following points 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.

Enhancing and Enriching the Teaching and Learning of STEM

When directly supporting the pipeline, engineering is viewed as curriculum.   Used to enhance and enrich the teaching and learning of STEM, engineering is viewed as a curriculum or methodology for teaching one or more subjects or for demonstrating the relationship between one or more subjects. In this sense, engineering would complement the learning objectives of other subjects, particularly science, technology, and mathematics. Indeed, a fundamental understanding of engineering is considered an important attribute of both scientific and technological literacy. The problem solving orientation and teamwork characteristics of engineering, which are also (essential) 21st Century workforce attributes, are considered by some to directly support elementary and secondary school objectives. Many in science and mathematics education believe that engineering, specifically the engineering design process, provides valuable context, application opportunities, and motivation for student learning and teacher engagement.

Some educators believe that engineering can reinforce scientific inquiry and the scientific method, and to illustrate and help students conceptualize scientific and mathematical concepts. In recent years, the NSF has funded a number of curriculum projects that use engineering as methodology for demonstrating the interdisciplinary nature of mathematics, science, and technology. NSF has also funded a considerable number of university-developed curriculum projects designed to create engineering-based learning modules and professional development activities for K-12 teachers.

With respect to the "value" of using engineering to enhance and enrich the teaching and learning of STEM in K-12, we obtained the following points from the literature:

- 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.

A number of challenges exist to using engineering to enhance and enrich the teaching and learning of STEM in K-12. Issues of teacher certification and professional development must be dealt with. As a practical matter, schools are constantly being asked to accommodate additional content in an already crowded curriculum, a situation aggravated by "high stakes" testing. Without a fundamental knowledge of engineering, curriculum developers may not be able to make the "content connections" between engineering and other subjects. Similarly, they have difficulty establishing appropriate learning outcomes and effective instructional strategies for effectively using and integrating engineering concepts.   Policy makers concerned about student achievement in STEM must assess the potential value of using engineering as "methodology" with little or incorrect information to assist them in decision making.

Creating a Technologically Literate Citizenry and Society

We define technological literacy to be "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". Conventional wisdom holds that (1) we live in a world that is increasingly dependent on technology; (2) technological literacy is an essential component of job readiness, citizenry, and life skills, (3) given the ever increasing importance of technology in our society, it is vital that Americans be technologically literate, and (4) to be technologically literate requires understanding the nature of science and technology. From a societal standpoint, a technologically literate citizenry, with special emphasis placed on decision makers and public policymakers, improves the chances that decisions about the use of technology will be made rationally and responsibly. A generally held belief is that Americans are poorly prepared to think critically about today's important technological issues. According to one expert, we know a great deal about people's opinion 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. Students are generally considered to be technologically literate if they can do the following. An engineering-based curriculum is well suited help accomplish these learning objectives.

- 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.

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, 13] http://www.iteaconnect.org/ and the publication of *Technically Speaking*: *Why All Americans Need to Know More About Technology* [Pearson, 25] 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 (1) know and appreciate engineering, (2) understand the role that design and engineering play in the creation of technology, and (3) be able to carry out engineering design activities [Meade, 21].

ACHIEVING THE GOAL OF NATIONWIDE INCLUSION OF ENGINEERING IN THE K-12 CURRICULUM

There are many who believe that the current curricula, instructional strategies, and emphasis on rote learning will not produce the higher order thinking and analytical skills needed of the 21st Century workforce. What is needed, they claim, are new methods of teaching, new and innovative (cognitive-based) instructional strategies (i.e., a move to student-centered learning), and new approaches to teaching and learning. We are passionate in our belief that the inclusion of engineering in the K-12 curriculum, nationwide, provides the opportunity to make these changes. So what does a reasoned approach require? First, a commitment from the engineering community; second, leadership in the form of a "champion"; third, identifying and engaging the "stakeholders; fourth, a series of strategically crafted alliances, collaborations, and partnerships; fifth, engineering standards of learning; and sixth, more programs like the one at Colorado State University (engineering and education partnership) for producing teachers. The National Academy of Engineering (NAE) and the National Research Council (NRC) have recently undertaken a project, *Understanding and Improving K-12 Engineering Education in the United States*. The goal of this project is "to provide carefully reasoned guidance regarding the creation and implementation of K-12 engineering curricula and instructional practices, focusing especially on the connections among science, technology, engineering, and mathematics education". The results of the study are expected to be available on 2008. We anticipate that the results can be used by the states to develop and implement K-12 engineering curricula. In our opinion, a major responsibility for securing the political and economic capital to develop and implement K-12 engineering curricula rests with the engineering school deans, both collectively and individually by state. At the state level, they 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) and a coalition of professional engineering societies are best suited to accomplish this task.

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