The Overlooked STEM Imperatives:

Technology and Engineering

K–12 Education

International Technology Education Association

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ITEA

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Technology and Engineering K–12 Education

Introduction

The superiority of a country as a leader in technology is a desired quality. The ability of an educational system to produce individuals with technological abilities is also a desired quality. You are invited to explore the power and promise of a STEM (science, technology, engineering, and mathematics) education through this publication—but more importantly, to seek to understand the importance of ensuring that the "T and E" are equal partners within STEM in order to adequately prepare the next generation workforce and produce valued contributors to our communities and society.

Education should be the cornerstone in terms of helping students to be creative problem solvers while, at the same time, helping to shape their futures. These characteristics are essential to our health, happiness, and safety. Technology and engineering, while being a part of a solid STEM education, create unparalleled experiences to apply technology, innovation, design, and engineering in solving societal problems. Such problems may range from the evolution of new farming equipment to safer drinking water or food to electric vehicles and faster microchips. Students must be able to apply their knowledge to improve people's lives in meaningful ways. As creative problem solvers, students can gain a vision for how something should work and become dedicated to making it better, faster, or more efficient. The latest science, tools, materials, and technology can be used to bring these ideas to life.

STEM education is important if we are to have a society that is to thrive, contribute in a meaningful way towards building our own future, and provide students with a need to achieve. No school subject unleashes the spirit of innovation like technology and engineering education. From research to real-world applications, technology and engineering education consistently helps students discover how to improve human lives by creating bold new solutions, connecting science to life in unexpected, forward-thinking ways. No other area of education can turn so many ideas into realities. Few have such a direction and positive effect on the everyday lives of people. We must count on technology and engineering teachers and their students' imaginations to help us meet the needs of the 21st Century. This area of education is inherently practical, creative, and concerned with human welfare, while at the same being an emotionally satisfying calling.

It is impossible to imagine a life without technology and engineering. Technology and engineering education can start at the earliest grade levels and continue through university experiences to study the grandest skyscrapers, personal transportation vehicles, and microscopic medical devices. It is impossible to imagine a sound comprehensive education without the study of concepts and principles that involve technology, innovation, design, and engineering at the K-12 grade levels.

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Introduction

Imagine an education based on thoughts that turn ideas into reality, is designed to work wonders, deliver the power "to do," is bolder by design, and can be the next big thing in education. Imagine an education that is called technology and engineering education and imagine that it exists in our schools today and tomorrow.

Despite the obvious need, an education of this nature faces inadequate support at this point in history. It is an old idea whose time MUST come if we are to continue to be a nation of inventors and innovators. We can design education to purposefully create and advance human invention and ingenuity. However, such an education must gain support within and outside of the education community to reach its full potential.

This publication is about an important way of thinking that involves designing and creating in our technological world known as technology and engineering education. Yet, it is an unnoticed, overlooked imperative in the education of ALL students. It is often overlooked by our greatest corporate, political, and educational leaders who value the importance of design, invention, and innovation as key components to a thriving economy and country. As the STEM education movement gains momentum, our leaders cannot continue with the mentality that our society moves forward on mathematics and science alone. It is the technology and engineering component of STEM that unleashes one's capability to create and adapt, using technological problem solving in the resolution of major societal problems. Until leaders start using every component of the STEM subject areas, our educational system will not begin to realize its full potential in creating the next generation of thinkers—with a complete set of skills that will lead us toward new innovations in a way that we have never experienced. Our current "overlooked imperative" must become a "national imperative" for students to reach their full potential as world leaders in STEM knowledge and practice.

We thank and appreciate the many writers, researchers, and practitioners from the STEM community and ITEA membership who have provided the thoughts that are consolidated into this introduction.

Imagine an education based on thoughts that turn ideas into reality...

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Background and History of the STEM Movement

Gerhard Salinger, National Science Foundation
and Karen Zuga, The Ohio State University

STEM (Science, Technology, Engineering, and Mathematics) education is currently a hot policy issue that is being touted as a means of maintaining the United States' position of world leadership in technological innovation and undergirding its economic prowess. The rhetoric emphasizes the need for motivating more K-12 students to become scientists, engineers and technicians. What is the history of STEM education and where is it going?

Interest in education involving the study of STEM subjects began in the colonial era when Benjamin Franklin wrote in *Proposals Relating to the Education of Youth in Pennsilvania* [sic] (Franklin, 1749) that topics such as grafting, planting, inoculating, commerce, manufactures, trade, force and effect of engines and machines, and mechanics ought to be taught. Rensselaer Polytechnic Institute was established in 1824 as the first technological university in the English-speaking world to teach the practical arts to the sons and daughters of the tenants on the van Rensselaer feudal landholding. As a result of the Land Grant Act of 1862, agricultural and mechanical institutions were created, with several of them—such as The Ohio State University—developing manual training teacher education as a part of the engineering program in the latter part of the century. As creation and use of technology grew over the intervening years, multiple efforts to institute and teach about technology have been initiated and employed in schools with that history, culminating in today's subject matter in the curriculum. Since the Vocational Education Act of 1917, the federal government has been financially supportive of career and technical education, and more recently the National Science Foundation has been involved in funding innovation and research in STEM education.

From its beginning in 1950, the National Science Foundation funded education. In the first years, funding was primarily for graduate student fellowships. But, at the urging of Congress, summer institutes for science and mathematics teachers were funded in almost every state by the late 1950s. With the launching of Sputnik, innovative curricula in physics, chemistry, biology, and mathematics were funded, usually to scientists and mathematicians. The Foundation began funding applied research in the early 1960s, but its role was under discussion until 1979 when the Engineering Directorate was established. The Education Directorate was reduced to providing graduate fellowships for about two years in the early 1980s. Spurred by *A Nation at Risk* (National Commission on Excellence in Education, 1983), the Education Directorate was recreated as the Directorate for Science and Engineering Education, and it grew to include the Division of Undergraduate Science, Engineering and Mathematics

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Education (USEME), which funded undergraduate laboratory equipment and courses: A Division of Materials Development, Research and Informal Education, and a Division of Teacher Enhancement and Preparation, among others. In 1991, the Directorate for Science and Engineering Education was reorganized and renamed the Directorate for Education and Human Resources with emphasis on STEM education for ALL, although it was still largely science and mathematics education. The interest in technology education increased, and Congress mandated the Advanced Technological Education program to develop technicians for the high-performance workplace. In the early 2000s, the Assistant Director for Education and Human Resources at NSF coined the acronym STEM for Science, Technology, Engineering, and Mathematics to replace SMET. The Directorate 's emphasis has now moved toward educational research and evaluation to know what works, with whom, and under what circumstances.

In the 1950s and 1960s, the precollege division emphasized disciplinary content and process. The instructional materials emphasized hands-on work and inquiry science. High school science courses in biology, chemistry, earth science, and physics were developed by leading scientists, e.g.: *CHEMStudy*, *Chemical Bond Approach*, *Physical Science Curriculum Study*, and *Earth Science Curriculum Project Investigating the Earth*. The green (environmental), blue (molecular), and yellow (organism) versions of high school biology were created in *Biological Sciences Curriculum Study*. (To find out more about these and other curricula to which we refer, use Google.) Each of these curricula profoundly changed content and pedagogy from the "read about" texts and "cook book" laboratories of the traditional texts. Inquiry was the pedagogy, with students asking questions and doing experiments. These curricula continue to influence the development of materials even today. However, these curricula were to educate students to "fill the pipeline."

Until the 1960s, science for the elementary school consisted largely of teachers telling things to students—if teachers, who were often not comfortable teaching science, included it in the school day at all. Nobel laureate physicist Bob Karplus began doing experiments with elementary school students, and an alphabet soup of curricula were developed including one for students with physical handicaps. One of the

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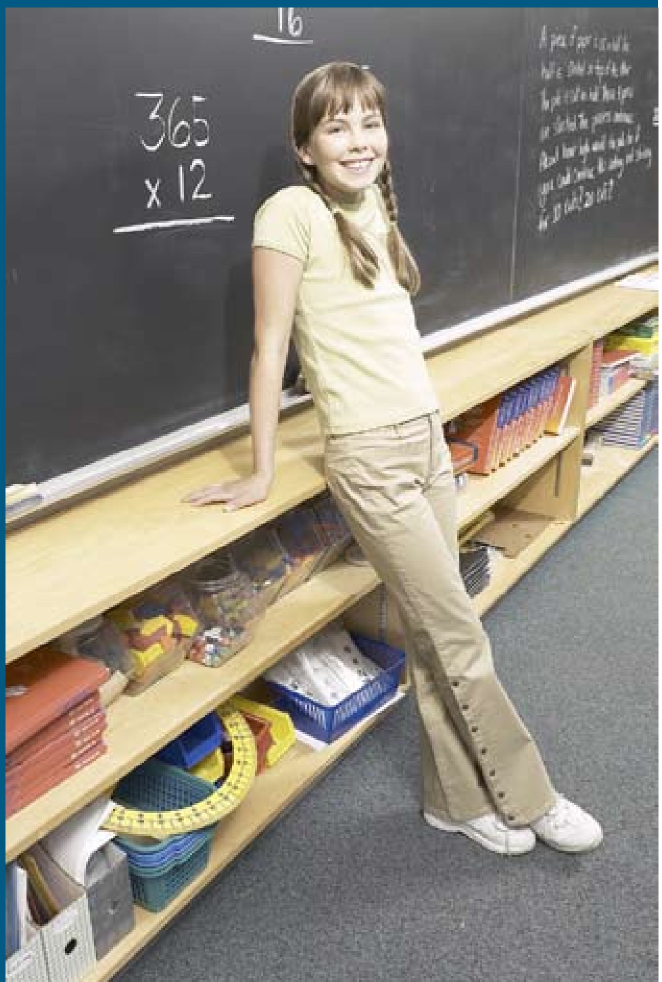

elementary school curricula was *Unified Science and Mathematics for Elementary Schools* (USMES), developed at Educational Development Corporation by an MIT engineer and teachers. Students could carry out long-range investigations of real and practical problems based in their local environment. The USMES philosophy centers on the fact that multiple factors contribute to real-world problems. USMES activities are challenges, which may be handled at various levels of accomplishment by students across a wide range of grades. Solutions to such problems often involve overlap between natural sciences, engineering, social sciences, and mathematics. In fact, classes are encouraged to interpret the challenge, narrowing the statement of the problem to a specific one that they are able to operationalize. Students then enumerate the tasks to be done and decide on a specific course of action and delegation of responsibilities.

In mathematics education, the reaction to the development of the "New Math" spurred research into mathematics education, especially at the elementary and middle school levels. These gave rise to *Principles and Standards for School Mathematics* (National Council of Teachers of Mathematics, 2000) and successful curricula to engage students in learning some of the mathematics in context.

The Man Made World was published in 1971. The chapter titles include Technology and Man, Optimization, Modeling, Systems, Feedback, Stability, Machines and Systems for Men, Logic, and Circuits as Building blocks. The last section of each chapter is called Laboratory and Projects and focused on application and context. The Sloan Foundation funded The New Liberal Arts, which also emphasizes the *Human Made World*. In the 1980s, the Instructional Materials Development program funded a number of projects with a technology and engineering basis for students at all levels, but there was often no place in the schools to teach them.

In the 1990s, NSF funded the development of instructional materials that integrated science, mathematics, and technology. At the middle school, a series of activities such as *TSM Integration Activities* (LaPorte and Sanders, 1993) and a comprehensive curriculum, *Integration Mathematics, Science, and Technology* (IMaST) (Satchwell and Loepp, 2002) were developed. At the elementary school level, *Project UPDATE* (Todd) and *Engineering for*

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Children (Hutchinson) provide design experiences for students and professional development for teachers. Several states developed technology education standards and, notably, Massachusetts incorporated technology standards into science standards. Jim LaPorte and Philip Reed (2001) did a study of topics of papers presented at the International Technology Education Association. Prior to 1990 there was about one paper per year on the integration of mathematics, science, and technology. After 1990 the number rose linearly for several years. More recently the number of papers on engineering education appears to have risen dramatically each year.

Project 2061 of the American Association for the Advancement of Science (AAAS) published *Science for All Americans* (Rutherford and Ahlgren, 1991) to answer the question, what should all students know about STEM when they leave high school. This monograph also had sections on technology education, social studies, and mathematics, and not only addressed the content but the habits of mind as well. It was quickly recognized that reaching a goal also needed benchmarks. AAAS developed the *Benchmarks for Science Literacy* (1993) at the same time that the National Research Council developed the *National Science Education Standards* (1995). Fortunately, the two sets of standards, both funded in part by NSF, are reasonably consistent and both include standards for technology. In the 1990s, the International Technology Education Association, with funding from NSF and NASA, developed *Standards for Technological Literacy: Content for the Study of Technology*, (ITEA, 2000/2002/2007), published with a forward from the president of the National Academy of Engineering. The National Academy of Engineering also published reports to encourage the teaching of technology and engineering—*Technically Speaking* (2002)—and on assessment in technology education—*Tech Tally* (2006).

Most recently, the NSF funded a middle school curriculum, *Problem-Based Inquiry Science* and high school science curricula, *Active Physics*, and *Active Chemistry* (all published by Its About Time Publisher) that use design challenges to motivate and assess science learning. The Materials World Modules are enrichment units that use design to teach about materials science and engineering. (Chang, 2009) Other materials developers are increasingly interested in the use of engineering design and real-world contexts to motivate student engagement. However, the recently completed National Academy of Engineering study (National Academies Press, 2009) finds that students take ownership of design experiments and questions in ways that are not engendered by single-answer questions, but in general the materials are very weak on the use of mathematics. When mathematics and science knowledge are related to the technology and engineering content, student learning of content and subject matter is approached in a way that addresses variation in learning styles.

We are beginning to have evidence that one does not become a technician or an engineer from simply studying science and mathematics. In order to achieve that expertise, one has to study technology and engineering, and children do not learn about technical careers without such subject matter in the school. (Cunningham, Lachapelle, & Lindgren-Streicher, 2005). The Museum of Science in Boston is developing *Engineering is Elementary* (Cunningham, 2004-2009) and has embedded engineering design in materials that can be used for both science and language arts for the elementary school.

NSF had a program called Bridges to Engineering Education in which proposals had to be submitted with a letter from both the Dean of Engineering and the Dean of Education at an institution. One outcome was to be some materials, but the real outcome was to be an ongoing viable interaction between the schools of education and engineering to get more engineering in the education of teachers and more education into the engineering programs. Unfortunately, this has not been continued. Engineering schools such as Virginia Tech, Purdue, and Arizona State have departments of engineering education that investigate K-12 education as well. Recently NSF has funded a National Center for Engineering and Technology Education at Utah State University to produce more educational researchers with an appreciation for K-12 engineering and technology education.

At the same time, there continued to be concerns about the place in the curriculum for technology or even integrated activities. The accountability movement stressed language arts and mathematics, with an emphasis on calculation and symbol processing crowding out other ways of learning. Technology education activities began to emphasize design, but the designs did not require much understanding of science or use of mathematical analysis. This might be noted as S.T.E.M.—STEM in four silos. The American Society for Engineering Education (which has established an Engineering K12 Center) is one of several organizations that recently became interested in engineering design, which requires more application of science and use of analysis. Also, with the name change from vocational education, career and technical education is taking technical education seriously, and engineering courses have become quite popular.

There is still confusion about the meaning of STEM education. Some people believe erroneously that technology is really about instructional technologies, but this would put three subjects—science, mathematics and engineering—in parallel with a tool—instructional technology. The preponderance of what is called STEM still focuses on four silos of varying magnitude. In some places, such as Virginia Tech, there is a concerted effort to develop an integrated STEM education program. One could argue that engineering education really is STEM education. Whereas silos emphasize synthesis of disciplinary knowledge to do applications, engineering involves inquiry in the design process to think critically and to solve problems. The principles of science and the analysis of mathematics are applied to technological problems of benefit to society. The learning is in relevant contexts and uses hands-on activities to engage students. Twenty-first century skills of teamwork, communications, and leadership are all practiced in the development of a solution to a problem. This is STEM.

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Chapter 2

The Power and Promise of a STEM Education:
Thriving in a Complex Technological World

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Throughout the United States, science, technology, engineering, and mathematics (STEM) education continues to gather momentum. STEM education is rapidly becoming part of the school experience. Technology and engineering (TE) activities are being infused in the learning experience, thereby integrating many areas of the curriculum.

Like never before, today's technology and engineering educators have an opportunity to play a lead role in transforming the K-12 classroom. However, the window of opportunity for our discipline to respond as leaders in transforming the school experience is getting smaller. It is critical that technology and engineering educators nationwide respond in a timely and effective manner.

Technology and engineering teachers can enhance student learning and excite and stimulate interest in learning science, math, and other school subjects through the use of projects in hands-on STEM education. The sharing of technology and engineering education practices and ideas is needed by all educators creating our future today.

STEM education has the potential to impact lives. Children who are coming through K-12 classrooms now expect real-world connections to what they are learning—or they disengage. As a means of learning, action-oriented hands-on technology and engineering education can bring the real world into the classroom. Children's lives are being enriched by the active study of technology and engineering, thus promoting students' natural curiosity. They learn best by doing.

STEM Education: *Making a Difference*

Science, technology, engineering, and mathematics (STEM) education has the potential to make a difference in young peoples' lives. Without a diploma, they'll head down a path that leads to low-paying jobs, poor health, and the continuation of a cycle of poverty that creates immense challenges for families, neighborhoods, and communities.

STEM education can increase relevance in the educational experience while decreasing the dropout rate. Higher expectations and a more challenging curriculum, coupled with the support students need to be successful, have proven to be an effective strategy not only for increasing graduation rates but also for preparing students for

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work or advanced education.

In the United States, nearly a third of all high school students do not graduate on time; among Blacks, Hispanics, and Native Americans, the rate is almost half. The National Dropout Prevention Center (NDPC) at Clemson University reports that the graduation rate is not improving. Why are our children dropping out of school? According to the NDPC, dropping out of school is related to a variety of issues that can be classified in four domains: individual, family, school, and community factors. Youth leaving school early is a process that transpires over time. Further, we know children disengage from our schools very early. In the United States this year, an estimated 1.25 million kids will leave school without earning a high school diploma. That is approximately 7,000 students every day of the academic year.

Although the reasons for dropping out vary, the consequences of the decision are remarkably similar. Students who drop out of school earn less, suffer from poorer health, and are more likely to wind up in jail than their diploma-earning peers. These young people will earn much less than an "average" high school graduate over their lifetime, and they are more likely to rely on public assistance.

Our education system has a responsibility to prepare students for the challenges and opportunities of the 21st Century, the century in which these students will spend their adult lives. STEM education offers students the opportunity to analyze and develop questions to find answers. This approach to education does not require expensive equipment or facilities; however, it does provide learners the opportunity to enhance the knowledge of analyzing and answers. STEM activities can be introduced into the classroom with very little expense. Many elementary school teachers are using recyclables or inexpensive or scrap materials for creative STEM activities.

STEM education encourages young people to investigate their world and contribute to it. It can give real meaning to learning by integrating technology and engineering education into all areas of the curriculum. STEM can encourage students to think with flexibility and confidence. When children are interested in their learning, they learn more. Introducing very basic STEM

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Every student in K–12 grades needs to have opportunities to experience the study of STEM.

topics early on in a student's school experience makes sense.

STEM Education:
Technological Literacy for Everyone

The power and the promise of STEM education is based on the need for technological literacy. People need to be able to:

- **Use Technology** – successful operation of key products and systems of the time; knowing components of existing macro-systems, or human adaptive systems, and how the systems behave.
- **Manage Technology** – ensuring that all technological activities are efficient and appropriate.
- **Understand Technology** – more than facts and information, but also the ability to synthesize the information into new insights.
- **Evaluate/Assess Technology** – being able to make judgments and decisions about technology on an informed basis rather than an emotional one (ITEA, 2003).

Technologically literate people can change the natural world to fit desired needs and wants. They are able to analyze problems, issues, and trends and respond to challenges with adaptability and flexibility. STEM education is a key pathway to technological literacy for everyone**.**

STEM Education:
Project-Based Learning Activities

Curiosity is at the heart of young people. By nature, they wonder about how things work. Early in a child's school experience, the child needs more opportunities to engage his/her curiosity and to be innovative. Children need to design, create, and experience hope for a future. Every student in K-12 grades needs to have opportunities to experience the study of STEM. By participating in STEM-related learning experiences, students can become technologically literate. Students today are our next generation of technology and engineering leaders.

By starting STEM experiences early in elementary education, we can help young people develop an understanding of complex technological processes as well as the differences between the natural world and the human-made world. Children become more excited and confident in math and science when using technology, innovation, design, and engineering to make school subjects personally meaningful. We must help elementary educators engage creative minds and ignite young ideas. Because of the complexity of today's technological processes, children need to learn early in their school experience to explore the differences in the human-made world and the natural world so that, ultimately, our young citizens can succeed and add to the social capital of our communities.

The inclusion of innovation and design through STEM education should begin in early elementary school and be nurtured on through middle school, high school, college, and beyond. This will take a concerted effort on the part of educational partners at all levels of education. All of us who have a stake in the future of our society can personally take action to help make technological literacy a central concern for the educational system.

Action-based, hands-on-activity learning is at the core of technology and engineering education. Project-based learning in technology and engineering education is a dynamic and activity-based approach to teaching that allows learners to explore real-world problems and challenges, simultaneously developing cross-curricular skills while working in small collaborative groups. What better place to accomplish this than through STEM education?

Project-based STEM education can inspire learners to obtain a deeper knowledge of the subjects they are studying. Learners are likely to retain the knowledge gained through technology and engineering project-based learning more readily than through traditional textbook-based learning. Moreover, learners develop confidence and self-direction as they move through both team-based and independent work.

In the process of completing their projects, students can refine organizational and research skills, develop better communication with peers and adults, and often work within their communities while seeing the positive effects of their work.

Because students are evaluated on the basis of their projects, rather than by exams and essays, assessment of project-based technology and engineering work is often more meaningful to them. Learners quickly see how academic work can connect to real-life issues. Learners can be inspired to pursue a career or engage in activism that relates to the project they developed.

Learners are motivated to learn and do quality work on projects that are valued by audiences they have identified. Human beings desire appreciation. Learners take pride in their work when they know someone important to them is going to view and appreciate their work. What better place to create quality projects than through technology and engineering activities?

Learners thrive on the greater flexibility of project-based learning activities. In addition to participating in traditional assessment, learners might be evaluated on presentations to a community audience they have prepared for, informative tours of a local historical site based on recently acquired expertise, or screening of a scripted video production they have produced.

Additionally, project-based technology and engineering education can be an effective way to integrate educational or instructional technology into the curriculum. Typically, a project can easily accommodate computers, the Internet, interactive whiteboards, global positioning system (GPS) devices, digital, still, and video cameras, and related editing equipment.

Adopting a STEM project-based approach in the classroom or school can energize the learning environment, revitalizing the curriculum with real-world relevance and igniting learners' desire to explore, investigate, and understand their world. Students embrace learning through STEM projects, a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks.

Project-based STEM education is a successful approach to instruction for a variety of reasons. STEM education can help students retain information; motivate and engage students' interest; encourage learners to explore interests and make connections to the world beyond school; encourage a deeper level of thinking by involving students in answering questions for themselves, make connections, and use analytical skills; and can possibly keep some children from dropping out of school.

Integrative learning of science, technology, engineering, and mathematics is not another thing to teach, but an excellent way to teach the current curriculum. Technology and engineering education is based on students' natural curiosity, providing opportunities for learners to experience how things work, how to put things together, and how to take things apart.

STEM Education: *Implementation Support*

The International Technology Education Association (ITEA) can provide support for successful implementation of STEM activities in your school. You can make a difference in implementing STEM education by joining ITEA (www.iteaconnect.org) and educators across the country in promoting the technological literacy standards and STEM education (www.iteaconnect.org/TAA/PDFs/xstnd.pdf). The promise of the future lies not in technology alone, but in people's ability to use, manage, evaluate, and understand technology. Together we help our children realize that through quality STEM education they, too, can become participants who can literally change the world in which they live.

The American Society for Engineering Education's (ASEE) Engineering K12 Center (www.asee.org) has created a website providing K-12 educators with engineering education resources. The website provides comprehensive data on outreach programs, career guidance materials, and access to hundreds of links and other materials related to engineering education. The ASEE Engineering K12 Center offers useful, easily accessible materials tailored to all parties with an interest in STEM education. The center works to enhance achievement in precollege science, technology, engineering, and mathematics (STEM) education by promoting the effective application of engineering principles to K-12 curricula. K-12 teachers can learn to teach engineering even with no exposure to the subject. With the help of ITEA and ASEE, teachers can learn the technology and engineering principles involved in educational units without knowing them in advance.

Hands-on activities and project-based learning are fun and effective ways to help students learn and retain more math and science concepts. By choosing STEM, educators can help students make the links among classroom learning, their everyday lives, and the broader world. Project-based learning can help students visualize abstract science and math concepts. Using hands-on activities, engineering design serves as the bridge to bring real-world relevance to math and science concepts. This bridge makes our designed world more understandable, relevant, and fun.

By promoting technology and engineering as viable career options, teachers help provide a stronger workforce in all fields of STEM, help create a technologically literate people/society, and provide students with the skills they will need to thrive in a technological society. By learning about technology and engineering in elementary, middle, and high school, students can see that it's one of the best ways to make our world a better place. Through problem-solving activities, students begin to see that we live in a designed world, and it's up to their generation to be creative and design better technological devices—like mobile phones, laptop computers, or video games.

Technology and Engineering Educators: *Leading by Example*

Technology and engineering educators are in a perfect position to assist K-12 teachers in making sense of STEM education. Technology and engineering teachers can help other content area teachers understand the importance of the integration of STEM subject areas with other subject areas. Through the introduction of STEM, they can lead the way in exploring teaching and learning many school subjects.

By choosing to teach and promote technology and engineering education, we can help learners make the connections among classroom learning, their everyday lives, and the broader world. Technology and engineering can reflect creativity, innovation, and learner engagement. Hands-on activities and project-based learning are fun and effective ways to help students learn and retain more math and science concepts. Our goal should be to find new and exciting ways to promote technology and engineering career options.

In technology and engineering education, the role of the teacher needs to be that of a facilitator who guides students through the learning process. Teachers become learners themselves, focusing on assisting students in learning *how* to think, not *what* to think. Learners learn to evaluate processes and then revise the process to make it more efficient. Learners learn to think for themselves. Students learn that it is okay to fail and that they learn from their experiences.

Technology and engineering lessons connect real-world experiences with curricular content already taught in K-12 classrooms. By mapping to educational content standards, technology and engineering teachers are in a unique position to take a lead in developing comprehensive curricula that are hands-on, inexpensive, and relevant to children's daily lives.

A STEM education starts with a creative child's first lesson in social studies, science, or math. The teacher who delivers that lesson, and the lessons that follow, is a technology and engineering educator. Especially now, with U.S. science and math learning in decline and technology increasingly driving global change, the job of delivering this education is more difficult. It is also more important than ever before.

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Summary

The International Technology Education Association is calling for and implementing the educational reform necessary to ensure technological literacy for all. Together we can help to create a stronger workforce in all fields of science, technology, engineering, and math (STEM) and help to create a technologically literate society. Together, technology and engineering educators can provide students with the skills necessary to thrive in a technological society.

Our profession needs your unique leadership abilities and skills to make an impact in transforming education in the next decade. Each of us needs to consciously practice our leadership abilities. We all need to be positive role models in our discipline. Clearly, each of us needs to be a proactive agent of change. We all need to challenge ourselves to lead by example. Our actions will be the measure of our success.

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Together, we can educate our students to be lifelong learners who can thrive in today's competitive global economy.

Several years ago, Price Pritchett, Ph.D. wrote *The Employee Handbook of New Work Habits of the Next Millennium*, outlining ground rules for job success. He stated that we must "think and see differently." The marketplace simply will not accommodate a lot of old belief systems about business, careers, and such. Prichett recommended that we change our minds to think from the angle of new realities. This will help position us to win in the new game of STEM education and technological literacy. Prichett recommended that we migrate to the fourth level of change, called "possibilities mentality." If you are a level-four performer, you are proactive, not reactive. Instead of waiting for change to happen, you make it happen. You're not content to cope with, adapt to, or even exploit change—you create it. We partner with the world of tomorrow and co-create change. We don't fight the future, we create it.

Together, we can educate our students to be lifelong learners who can thrive in today's competitive global economy. We can introduce them to technology and engineering skills and concepts that fuel innovation. We must provide opportunities for our learners to identify problems, design solutions, do testing, and improve the designs. We can help learners apply their math, science, and technological knowledge to solve problems while making use of the English language, art, history and social sciences. STEM education gives shape and meaning to our human-made world and can open doors for all kinds of learners.

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Supplemental Resources for Technology and Engineering Education

- http://edc.nasa.gov
- http://manufacturing.stanford.edu – An introductory website for kids and adults showing how various items are made. It covers over 40 different products and manufacturing processes and includes almost four hours of manufacturing video.
- www.coe.uga.edu/ingear/ – **Ingear** – Provides teachers and teacher educators with access to materials that will enhance their own understanding of gender equitable classroom practices and access to materials that can be used to help teacher-education students address issues of gender equity in their teaching.
- www.edequity.org – **Educational Equity Center** – Promoting bias-free learning through innovative programs and materials. It strives to decrease discrimination based on gender, race/ethnicity, disability, and level of family income. Includes information on programs and materials as well as training.
- www. iteaconnect.org – **International Technology Education Association**
- www.nctm.org/equity.aspx – **National Council of Teachers of Mathematics: Equity Resources** – Features equitable resources to encourage teachers and students to value and respect the work of all members of the classroom community and to believe that all students can make important contributions.
- www.ncwit.org/ghit – **National Center for Women & Information Technology (NCWIT): Gotta Have IT** – A computing resource kit designed with K-12 educators' needs in mind: a select set of high-quality posters, computing and careers information, digital media, and more, the resource kit builds awareness and inspires interest in computing.
- www.preK-12engineering.org – Resource for educators and administrators seeking to integrate engineering concepts and activities into Pre-K through twelfth grade.
- www.sallyridescience.com/for_educators – **Sally Ride Science: For Educators** – Features innovative science content dedicated to supporting girls' and boys' interests in science, math, and technology. A key part of the mission is to make a difference in girls' lives and in society's perceptions of their roles in technical fields.
- www.stemtransitions.org – **STEM Transitions** – At the heart of the project are the six science, technology, engineering, and mathematics (STEM) career clusters that will provide the context for instructional materials demonstrating the convergence of academic and technical content.
- www.swe.org/iac/ – **The Society of Women Engineers Internet Activities Center** – Grade-appropriate materials on science or engineering.
- www.teachengineering.com – A K-12 teacher resource for hands-on technology and engineering.
- www.tryengineering.org – A resource for students (ages 8-18), parents, teachers, and school counselors.
- www.tryscience.org – A gateway to science and technology centers worldwide.
- www.washington.edu/doit/Stem/ – **AccessSTEM** – Where K-12 teachers, postsecondary educators, and employers learn to make classroom and employment opportunities in science, technology, engineering, and mathematics (STEM) accessible to individuals with disabilities, and share promising practices.

Chapter 3

The "T" and "E" in STEM

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For more than a decade, experts from across the United States have warned of a looming national crisis in the fields of science, technology, engineering, and mathematics. The crisis, as most suggest, is a looming shortage of professionals entering the fields of science, technology, engineering, and mathematics (STEM). Researchers and prognosticators alike predict anything from a loss of productivity and gross national product to a very real lowering of the standard of living in the United States if increased attention is not given to the STEM disciplines.

Supporting the STEM quandary in the United States, the National Research Council (2007) noted that just as the nation's economic engines and national security measures have come to rest squarely on the shoulders of the STEM fields, secondary and post-secondary students are turning away from science, technology, engineering, and mathematics in record numbers. Meanwhile, the National Science Board reported that the United States is currently experiencing a chronic decline in homegrown STEM talent and is increasingly dependent upon foreign scholars to fill workforce and leadership voids (National Science Foundation, 2008). Similarly, the Council of Graduate Schools (2007) noted that university graduate student admissions to some post-secondary STEM programs are down more than 30 percent over previous levels, and in some areas only 16 percent of the students in science and engineering disciplines were citizens of the United States. At the same time as students and professionals seem to be turning away, career opportunities in STEM fields seem to be exploding. A recent report from the U.S. Bureau of Labor Statistics predicts that the number of jobs in STEM occupations will grow by 47 percent—three times the rate of all other occupations by the year 2010 (AASCU, 2005).

All of this leads one to consider the urgency and timeliness of this publication and the necessity that the conversation not be confined to individual disciplines and their respective desires and issues, but rather to the entirety of STEM. Clearly, the fields of mathematics, science, engineering, and technology each have internal concerns and initiatives that exclude the others, but STEM education is more than, as they say, the sum of its parts. STEM education has the potential to prepare the next generation of students with enhanced skills to solve complex problems, consider consequences, think critically, collaborate across disciplinary boundaries, invent and innovate, and compete with the best the world has to offer.

Educational practices that invigorate teachers and engage students in science, technology, engineering, and mathematics (STEM) must be implemented to vastly change the way these critical disciplines are delivered in the nation.

For more than a decade experts from across the United States have warned of a looming national crisis in the fields of science, technology, engineering, and mathematics.

STEM education in K-12 education has never been more important, nor as much discussed. To address the persistent issues raised by state and national reports, as well as reports from business and industry, substantial efforts must be undertaken to improve elementary and secondary science and mathematics education as well as increased efforts to provide technology and engineering education for all precollege students. Identifying a field of study as a STEM discipline is a way of clarifying what is and what is not included in the STEM club. Unfortunately, while there is generally some degree of clarity about the “S” and the “M,” there is also widespread uncertainty by many about the other half of the acronym.

Numerous publications have emphasized the position that STEM plays in our national security as well as the present and future economic competitiveness and viability of the United States (AASCU, 2005; ITEA, 2000/2002/2007; NSF, 2003; NRC, 2007; Potter, et al). But while such an emphasis has been encouraging to those who have advocated on its behalf, two letters seem to have gotten lost in the middle of the acronym: the “T” and the “E”—or the technology and engineering—seem to be overlooked by many (Dieffenderfer, 2006). To support this assertion, consider the number of school districts and states that have increased mathematics and science requirements in recent years by adding courses, inserting mandatory high-stakes tests, and by championing rigor, and then consider the minority of school districts and states that have initiated comprehensive STEM education programs that address the “T” and the “E” in the STEM acronym as well as science and mathematics.

> *So, squeezed for time and resources, relatively few local school districts and states or provinces have opted for what they see as the luxury of including the study of technology as part of the core curriculum (ITEA, 2000/2002/2007, p. 3).*

It therefore seems reasonable to conclude that many educational and political leaders have yet to comprehend or accept the collective nature of STEM education and have rather attempted to address perceived problems by heaping on increased expectations and requirements for mathematics and science education. What these leaders fail to recognize or acknowledge is the potential that technology and engineering educa-

Educational practices that invigorate teachers and engage students in science, technology, engineering, and mathematics (STEM) must be implemented to vastly change the way these critical disciplines are delivered in the nation.

tion have for exponentially increasing the synergy and yield of STEM learning activities in the K-12 educational systems in America.

Dieffenderfer (2006) suggests that many policymakers and educators simply assume that if students learn increased levels of science and mathematics, they will have accomplished STEM education, and all will be well. While most would agree that a strong foundation and deep skills in mathematics and science are certainly important, preparing the next generation in these two disciplines alone will not address the dearth of STEM talent identified in most state and national reports. Students with little or no exposure to or experience with technology or engineering have a very low probability of engaging in those fields after schooling is complete (Dieffenderfer). The International Technology Education Association (2000/2002/2007) noted that, when taught effectively, technology was not simply one more field of study seeking admission to an already crowded school curriculum, but rather it serves to reinforce and complement the material that students learn in other STEM classes. Bybee (2000) noted that, for a society so deeply dependent on technology, we are largely ignorant about technology concepts and processes, and we have largely ignored this incongruity in our educational system.

"T" is for Technology

When considering the "T" in STEM, many mistakenly fall for one of two familiar misconceptions. First, many assume that the technology in STEM is referring to the implementation of computers and/or instructional technology devices and software. While computers are certainly a part of the equation in technology education, this definition is far too narrow an understanding and represents only one technological tool among many. Conversely, technology education should be viewed in the sense of a discipline dedicated to the study of all the modifications humans have made in the natural environment for their own purposes (Dugger & Naik, 2001).

> *"To be clear, the use of computers, as one of many educational technologies, is essential in this age. However, it should not be confused with the study of technology, which provides students with opportunities to learn about the processes of design, fundamental concepts of technology and engineering, and the limits and possibilities of technology in society" (Bybee, 2000, p. 23).*

This discipline, commonly referred to as technology education, includes the study and application of learning experiences related to inventions, innovations, and changes intended to meet human wants and needs. In short, if humans thought of it and made it, it's technology (Wonacott, 2001). The International Technology Education Association (2000/2002/2007) defines technology as the modification of the natural environment in order to satisfy perceived human needs and wants (p. 9).

The common assumption that the word technology in STEM is referring to computers is compounded by a second familiar misconception. When asked to define the word technology, many individuals suggest that it is the application of science or applied mathematics. Although this definition of technology has a long standing in this country (Stokes, 1997), it is well past time to establish a new understanding about technology (Bybee, 2000). Sanders (1999) indicated that while science and technology are closely related, there are fundamental differences. Science generates knowledge for its own sake by proposing and testing explanations, while technology, on the other hand, develops human-made solutions to real problems. Of course, science uses technology to generate knowledge, and technology uses scientific knowledge to generate solutions, so the two are integrally connected; but they are different fields driven by different concepts and processes (Bybee, 2000).

Technology education is a discipline devoted to the delivery of technological literacy for all. As a result of studying technology in Grades K-12, students gain a level of technological literacy that may be described as one's ability "…to use, manage, assess, and understand technology" (ITEA, 2000/2002/2007, p. 9). In the report, *Technically Speaking: Why All Americans Need to Know More about Technology* (2002), the National Research Council declared the overriding benefit of being technologically literate:

> *In a world permeated by technology, an individual can function more effectively if he or she*

> *is familiar with and has a basic understanding of technology.*

Further, the report suggests that to take full advantage of the benefits of technology, or even avoid some of the pitfalls of technology, we must become better stewards of technological change. The variety of technology available today is extensive, as are the human problems that technology might solve. As a result, individuals need more than just knowledge of the technology that surrounds them; they also need the skills and knowledge to use the new and changed technologies of tomorrow—they need to be technologically literate (Potter, et al. 2000).

Technology education programs in the K-12 schools are advancing, not with the goal of preparing students for the workplace or increasing the relevance of core subjects, but to provide all students with a measure of technological literacy. The goal is to prepare citizens who understand the nature of technology and its interaction with the other STEM disciplines and society (Cajas, 2001). It's the objective of literacy—core ideas, concepts, skills, and values that are important for all citizens—that connects science, technology, engineering, and mathematics. Cajas (2001) noted that:

> *Traditionally, the interaction between science and technology education has been seen in terms of dichotomies: technology is "doing," while science is "understanding," and so on. However, when we move to the arena of literacy in science and technology, these dichotomies no longer hold: there is a common body of scientific and technological ideas and skills that is relevant for the education of all students (p. 725).*

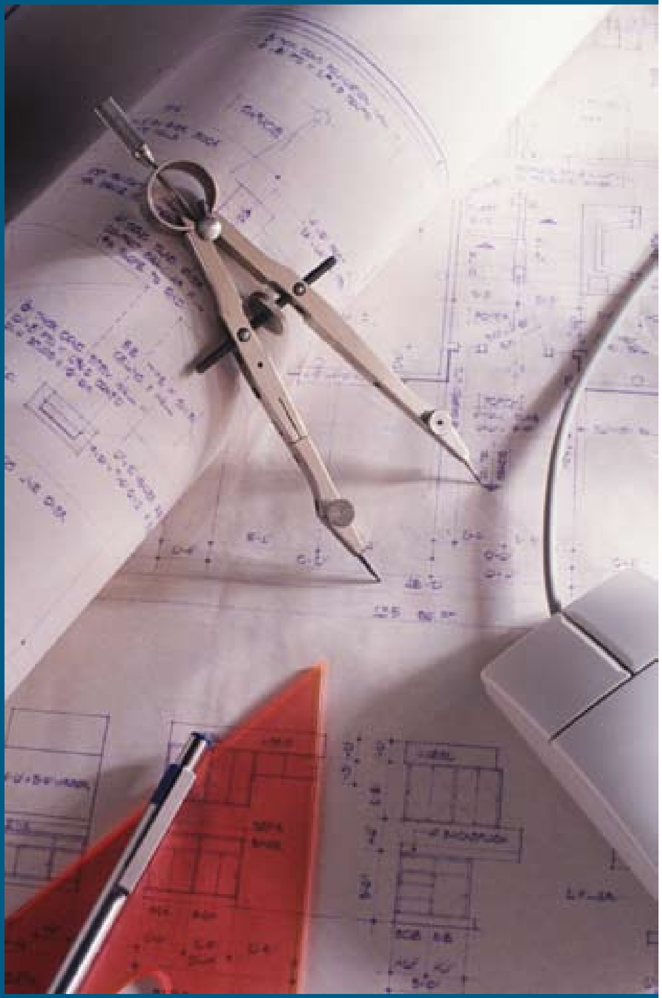
One of the great benefits of learning about technology in a K-12 classroom or laboratory is to conduct activities and experiments that reflect the development of technology in the real world. Recent research on learning finds that many students learn best in experiential concrete ways rather than only through visual or auditory methods—and the study of technology emphasizes and capitalizes on such active learning (ITEA, 2000/2002/2007). For these reasons and others, a growing number of leaders have called for the study of technology to be included as a core field of study in elementary, middle, and secondary schools (ITEA).

Although there is a common tendency to emphasize the positive impacts of technology, *Standards for Technological Literacy: Content for the Study of Technology (STL)* (ITEA, 2000/2002/2007) calls on all educators to examine the intended as well as the unintended consequences of technological development and proliferation. Moreover, the standards outline the core concepts of technology and the relationship between technology and society as well as the complex relationship between technology and the environment, among numerous other standards. One of the fundamental lessons of technology education is that while technology can be used to solve problems, it may also create new ones (ITEA, 2000/2002/2007). Bybee (2003) noted that one unfulfilled promise in American education stands out above the rest, and that is the technological literacy of all citizens. Technology education provides a pathway to that needed technological literacy for all (Deal, 2002).

"E" is for Engineering

Unlike the disciplines of mathematics, science, and technology, engineering does not have an historic home in K-12 education. Subsequently, efforts to include engineering content at the secondary level have historically resulted from university outreach programs, units included in science classes, demonstration projects funded by external agencies (i.e., National Science Foundation, etc.), and most prominently through insertion into the technology education curriculum. The relationship between technology education and engineering has always been strong, but the recent public emphasis on K-12 engineering has served to strengthen the bond and provide incentives for the two fields to complement one another at the secondary level.

The ties between engineering and technology education have also recently been strengthened through the development and publication of *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000/2002/2007). Both fields have a strong interest and a mutually beneficial need for a technologically literate citizenry. While leaders in technology education often view engineering as a core concept with applications for all students and citizens, engineers tend to view technological literacy as an avenue that can be used to gain entrance to the field of engineering. Reid and Feld-



Engineering uniquely connects the disciplines of mathematics, science, and technology education. Engineering is a way of understanding the human-made world, how it was created, how it functions, and how it might be changed...

haus (2008) supported this assertion when they noted that there is a movement by the engineering community to gain a better understanding of the K-12 issues that impact enrollment at postsecondary institutions, and to advance the state of engineering.

Given the broad interest in technological literacy, engineering and technology education can work in unison to promote K-12 educational programs that further core engineering concepts for all, as well as creating pathways to careers in engineering. Both fields have contributions to make. While technology education is recognized as the study of the human-made world, its artifacts and processes, engineering uses knowledge of science, mathematics, and technology to understand, design, and implement solutions to human problems.

Engineering uniquely connects the disciplines of mathematics, science, and technology education. Engineering is a way of understanding the human-made world, how it was created, how it functions, and how it might be changed (Burghardt & Hacker, 2009). Unlike scientific inquiry and mathematical analysis, engineering design does not seek a unique or correct solution, but rather seeks the best or optimum solution after a variety of factors are weighed, such as cost, materials, aesthetics, and marketability (Burghardt & Hacker). Likewise, Petroski (1996) suggested that the role of design is what most distinguishes engineering from science, which concerns itself principally with understanding the world as it is. Moreover, Petroski affirmed that:

> *Engineers throughout history have wrestled with problems of water not being where it was needed, of minerals not being close at hand, of building materials having to be moved" (p. 2).*

In this way, technology and engineering education use very similar approaches to the design process. However, technologists (or inventors and innovators) often use a design problem-solving process (or design loop) that includes less predictive modeling and analysis and more trial and error. Petroski (1996) noted that while engineering is a more highly mathematical and scientific endeavor, its practice still requires a good deal of commonsense reasoning about materials, structures, energy, and the like. Whereas mathematics and science help humans analyze existing ideas and their embodiment in "things," these analytical tools do not, in themselves, give us those ideas. Engineers have to determine how to alter nature and existing artifacts to better achieve objectives considered beneficial to humankind. In this way, the fields of technology and engineering education are inextricably linked by their common focus on the (engineering) design process. Technology educator and former Director of the Technology for All Americans Project, William Dugger once noted that:

> *[Design] is as fundamental to technology as inquiry is to science and reading is to language arts (ITEA, 2000/2002/2007, p. 90).*

Similarly, from the engineering community, William Wulf, former Director of the National Academy of Engineering, once noted that:

> *My favorite operational definition of what engineers do is, "design under constraint." We design solutions to problems. However, there are a set of constraints that we have to satisfy—size, weight, reliability, safety, economic factors, environmental impact, manufacturability, and whole list of "-bilities" (Wulf, 2002, p. 4).*

Design has been recognized as an essential part of technological understanding, and for many individuals the essence of engineering is design (Goldman, 1984).

Design: The Common Link between Technology and Engineering Education

Design is regarded by many as the core problem-solving process of technological development and engineering (ITEA, 2000/2002/2007). Koen (2003) noted that "design is the essence of engineering" (p. 28) and further suggested that design is the unique, essential core of the human activity called engineering. But for it, the engineer would not exist. Although alternatively called *engineering design*, the *engineering method*, the *design method*, *iterative design*, the *design loop*, and other names, for the purposes of clarity the concept/procedure will here be referred to as engineering design. Engineering design is the process of devising a system, component, or process to meet desired human needs and wants. It is an iterative decision-making process through which basic science, mathematics, and technological knowledge are applied to optimally meet a stated objective. In *Standards for Technological Literacy*, engineering design is described as:

> *A distinctive process with a number of defining characteristics: it is purposeful; it is based on requirements; it is systemic; it is iterative; it is creative; and there are many possible solutions (ITEA, 2000/2002/2007, p. 91).*

This description of engineering design seems equally well suited to either the field of technology or engineering education.

McNeill and Bellamy (1998) noted that, while each technological or engineering problem may have a unique solution, the underlying approach used to develop the solution is not unique. Effective problem solvers typically utilize a generic methodology that increases their probability of success. Although the literature presents a myriad of engineering design models or procedures for solving design problems, a methodology that is useful in both technology and engineering education consists of defining the problem clearly at the outset, gathering applicable research and related information, generating alternative solutions, evaluating or testing the alternatives through the use of models and prototypes, and finally communicating the results (Dieter, 2000). Beyond the engineering design process often used as a tool in technology education circumstances, engineering design processes used in the field of engineering frequently call for the formulation of a mathematical model or proof of the best system concept. The engineering design process can be applied to solve simple engineering or technological problems, design new products (whether they be consumer goods or highly complex products such as missile systems or jet planes), or to design complex systems such as an electric power generating station or a chemical plant, while yet another area is the design of a building or bridge (Dieter, 2000).

Regardless of the specific process used, the engineering design process may be best characterized by its iterative nature. The design of a new product or system is rarely as clear or linear as it seems when reading about it in history textbooks. The engineering design process is an iterative, creative, and nonlinear process that often requires backtracking and rethinking (Koen, 2003).

Engineers refer to the use of heuristics to describe the implementation of known facts or quantities that can be plugged in toward the potential solution of a problem. A heuristic is a plausible aid or direction in solving an engineering or technological problem that is in the final analysis unjustified, incapable of justification, and potentially fallible (Koen, 2003). Koen noted that:

> *Engineering design, or the engineering method, is the use of heuristics to cause the best change in a poorly understood situation within the available resources (2003, p. 28).*

Technologists do not use heuristics in the sense that engineers do, relying instead on the pragmatic implementation and/or adaptation of known solutions to similar problems. These solutions are tempered by experiences, societal values, and available resources. Hence, the optimal solution to a given problem implemented by a technologist and the one implemented by an engineer may differ greatly, just as the route to that solution may differ greatly—but both will have arrived at that solution using a version of the engineering design process. Because we can bring our values to our design solutions, engineering design can be a very engaging instructional activity (Burghardt & Hacker, 2009).

Summary

Technological wherewithal is essential in this age, and the STEM disciplines of technology and engineering education have a substantial role to play in preparing those individuals who will pursue careers in STEM, but perhaps more importantly, these two disciplines will play an increasingly vital role in preparing those citizens who will interact with STEM in a less apparent manner. Collectively, STEM programs should prepare all citizens to interact with existing technologies and plan for a future that they can't even imagine. Technology and engineering education will provide all K-12 students with the conceptual knowledge, design experience, and confidence to interpret what exists and improve upon it. The interaction between the natural inquiries of science, the analyses offered in mathematics, and engineering design offered in technology and engineering education will prepare future citizens who understand the limits, strengths, and possibilities of the natural and the technological world.

Clearly, the value of STEM education is greater than the sum of its parts. At the heart of STEM education is the interface between the disciplines, and for the desired synergy to occur advantageously, science, technology, engineering, and mathematics must all be at the table. In the science community, the result of such synergy is referred to as emergence—where the product of collaborative systems or organisms results in qualities not directly traceable to the individual components. Such emergence is also achievable and desirable in STEM education programs, but all members of STEM must be equally represented. Let us challenge educational leaders to invest in programs that include the optimum from all STEM disciplines and prepare citizens to thrive in a world where continual change and adaptation are the norm. A wealth of natural resources, ingenuity, and hard work provided the mechanisms that transformed our nation during the 20th Century. National and international transformations during the 21st Century will be driven by those who invest in and advance comprehensive STEM education programs.

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Chapter 4

The Contributions of Science and Mathematics to STEM Education:

A View From Beyond the Disciplines of Technology and Engineering

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We are pleased to have a chance to consider the contributions of our respective fields—science and mathematics—to STEM instruction. Occasionally insights from outside the field are fresh and inspiring; sometimes they are simply derivative and naïve. While we will hope for a positive response from readers with legitimate expertise in technology, this opportunity to examine the interface of the STEM fields has been interesting, refreshing, and empowering. In the pages to follow we will briefly examine technology and engineering education as these fields are represented in the science and mathematics standards and will provide some insights into the potential application of science and mathematics in STEM education. We will conclude with some thoughts about the ways in which all the STEM fields can cooperate more fully with each other. What is clear even as we begin this review is that the term "STEM" was chosen wisely; the potential for collaboration and cross fertilization for both teachers and students is vast, a theme we will explore further.

A Very Brief Introduction to Technology and Engineering Education

This section is included as much for our edification as for that of our readers who know these fields well. Our intent is to set the stage for the review that follows and to acknowledge several of the fundamental documents in technology education that have provided us a worthy introduction to the field.

Certainly two of the most important documents in technology education are *Standards for Technological Literacy: Content for the Study of Technology (STL)* (ITEA, 2000/2002/2007) and *Advancing Excellence in Technological Literacy: Student Assessment, Professional Development, and Program Standards (AETL)* (ITEA, 2003), which target instructors (ITEA, 2003). These well-articulated sets of guidelines have assisted us greatly in understanding the focus of the field and the place of technology education as a part of the other STEM fields. The standards document (*STL*) includes the term "science" more than 60 times, "mathematics" is found in more than 50 places, and "engineer" and/or "engineering" more than 150 times. We will soon see how well technology is represented within the national mathematics and science standards.

We have found the conceptual model of Custer and Erekson (2008) particularly enlightening in describing the distinction and overlap between technology and engineering. It has helped greatly in dispelling some of our misconceptions about the relationship of technology and engineering to each other and to our fields of science

We wish that the science and mathematics of STEM were as neatly aligned with each other as are the technology and engineering.

and mathematics. The overlapping wedges lead to and from technology and engineering. The model therefore describes the work, tools, and abilities necessary to be an effective craftsman on one hand while demonstrating the necessary shifts in this suite of attributes that must occur as the ultimate job changes from technician to designer to engineering technologist and, ultimately, to engineer. Skills such as troubleshooting and repair are gradually replaced by theory-based design; tools, processes, and design implementation give rise to engineering heuristics; while innate skills and abilities of the technologist ultimately give way to knowledge of math and science with the change in focus from craftsperson to engineer. We wish that the science and mathematics of STEM were as neatly aligned with each other as are the technology and engineering. Our review of the literature of technology and engineering education has also been instrumental in forcing us to think outside of the boxes of science and mathematics. The views and concerns of those who have added to the rich literature base in technology and engineering education have inspired us to consider the entire STEM field in a more holistic fashion. Our reading of some of the literature of technology education has revealed the relationships between the STEM disciplines instead of just the distinctions. In the following sections we will each consider how our respective instructional standards can be more vital elements of what should be a STEM continuum.

Skills such as troubleshooting and repair are gradually replaced by theory-based design; tools, processes, and design implementation give rise to engineering heuristics; while innate skills and abilities of the technologist ultimately give way to knowledge of math and science with the change in focus from craftsperson to engineer.

Technology and Engineering and the National Science Education Standards

National Science Education Standards (NSES) (NRC, 1996) has been the guiding document in science education for more than a decade. Even though it lacks the legal status held by the multitude of state standards it has spawned, *NSES* is the most frequently referenced set of guidelines both for content and for pedagogical practice in science education. It is striking that technology is mentioned scores of times and in dozens of places throughout *NSES*. In fact, among the first statements in the document is the recommendation that "Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology" (NRC, 1996, p.1).

This statement is followed by the admonition that teachers should be able to "make conceptual connec-

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tions within and across science disciplines, as well as to mathematics, technology, and other school subjects" (p. 59). This is accompanied by the strongest statement of the relationship between science and technology, a unique standard describing that relationship:

Science and Technology Content Standard E, Science and Technology, includes (Levels K-4):

- Abilities of technological design
- Understanding about science and technology
- Abilities to distinguish between natural objects and objects made by humans

and at Levels 5-8 and 9-12:

- Abilities of technological design
- Understanding about science and technology (NRC, p. 107).

The science standards also include an exceptional picture of the relationship between science and technology while making clear an essential distinction between the two endeavors. The agreement and distinction between science and technology will be emphasized in the sections that follow.

> *. . . the central distinguishing characteristic between science and technology is a difference in goal: the goal of science is to understand the natural world, and the goal of technology is to make modifications in the world to meet human needs. Technology as design is included in the Standards as parallel to science as inquiry. Technology and science are closely related. A single problem often has both scientific and technological aspects. The need to answer questions in the natural world drives the development of technological products; moreover, technological needs can drive scientific research. And technological products . . . provide tools that promote the understanding of natural phenomena (NRC, 1996, p. 24).*

Another element of the *NSES* standards is the explicit role expected for inquiry. The *NSES* document states that students will understand inquiry as the central investigative method of science, while teachers are expected to use inquiry as a pedagogical tool. This focus on inquiry is woven so tightly into the science standards that a secondary guide, *Inquiry and the National Science Education Standards* (2000), has been developed to help facilitate the dual expectation held for inquiry in U.S. science classrooms. Of course, one of the key tools of both technology and engineering is investigation through inquiry and problem solving.

It should be abundantly clear that the authors of *NSES* understand and have attempted to communicate the potential interplay between the disciplines of science and technology/engineering. The open question is whether and how the educational community has responded to this call for unity between science and technology instruction. In the world of benchmarks and end-of-course examinations it is likely that authentic unity will occur only when students—and teachers—are challenged to make the connections recommended by the standards.

The Potential Role for Science in Technology: Limits, Potentials, and Processes

It is clear that the national science standards strongly feature technology as a worthy partner in the quest for science literacy. However, it may be enlightening to consider the intersection of these disciplines free from the specific recommendations of the standards by examining the nature of the discipline of science itself and looking there for worthy links to technology and engineering.

During the past quarter century science educators have made considerable strides in helping to define the elements of science that should be communicated to science learners. These essential aspects are collectively known as the "nature of science" (McComas, 1998). Some have objected to the emerging list of elements and some have criticized the use of "the" in nature of science to encourage us to believe that there are many natures of science. Ultimately a high level of agreement has been reached regarding how we might best define the discipline of science for instructional purposes.

Some lists of the key elements of science feature the idea that science is distinct from technology (McComas, 2008). The distinction is based on an understanding that the discipline of "pure" science is unencumbered by utility in ways that technology certainly is not. At its core, *science* is concerned only with gaining the most accurate understanding of the natural world. In fact, the word science comes from the Latin for "knowledge" or "knowing." There are two basic kinds of knowledge of interest to scientists. First there is knowledge of the rules of nature, and second there is knowledge of the explanation for those rules (McComas, 2004). Put simply, the rules, patterns, and generalizations are the laws of science, and the explanations for those rules, patterns, and generalizations are theories—even though the central goal of science is to discover laws and propose theories, not to invent and improve products. However in very important ways, science does continually provide the *promise* of utility. It does so by defining limits, inviting potentials, and defining productive processes—notions that will be discussed next.

Science Defines Limits

The laws of nature discovered by scientists can be thought of as limits imposed on technologists and engineers. It is frequently said that only by knowing the rules can one break them. Unfortunately, while this may be true in some fields, it is not true in science. It is not possible to break the rules of nature. For instance, no matter how much engineers might like sound to travel through the vacuum of space, it cannot. Despite what we hear in Hollywood blockbusters, the thundering explosions on the screen will remain in the world of fantasy, not science, and represent a natural limit imposed on us all.

In engineering, knowledge of the rules of the game of science is vital when making products and engaging in design that result in the expected function. Designing a bridge without knowledge of the coefficient of expansion of the building materials would be fatal on the first very hot or very cold day. It is impossible to fool nature into behaving in ways contrary to the underlying physical properties of the construction materials. Failing to be mindful of the limits imposed by science is a recipe for failure no matter how wonderful it would be if these underlying limits did not exist. No matter what one wants to design, construct, or modify, the laws of nature must be obeyed, and as is often said, ignorance of the law is no excuse.

Science Suggests Potentials

It is possible to look at the rules or limits of science in another, more positive, way. Within this view, the rules of science might be called potentials. Engineers must learn about science in the abstract with an eye to seeing how nature might be put to the task of solving a problem—even one that was not known to exist. When laser light was first discovered, it was a curiosity—nothing more or less. The idea that a beam composed of parallel rays of light of a single wavelength would have any practical use was likely not at the top of the minds of Townes and Schawlow of Bell Labs who made the initial discovery of this unique form of illumination. However, it was not long before laser light in the hands of technologists and engineers became the laser itself, which is used in myriad ways, from a cutting tool to an information retrieval device in CD and DVD players and as a key element in many photocopiers. Laser light could have remained nothing more than a unique scientific discovery, but its potential did not remain untapped for long, and it now forms the backbone of a multibillion-dollar technological bonanza.

To be sure, many scientific discoveries simply serve to fill in the blank pages in our knowledge of the natural world, but who can say which may serve some highly practical and profitable purpose in the future.

Science Provides Investigative Processes

One of the most impressive and productive elements of science is contained in its method. However, here we are not talking about the "scientific method" per se, that somewhat apocryphal notion that all scientists follow an identical stepwise plan to answer questions and address problems. Rather, the method of science is a suite of elements including the requirement for evidence, that observations and experiments can be used to probe nature to provide the required evidence, that data should be carefully recorded and open to all for examination, and that the final conclusions are negotiated within the scientific community through peer review, publication, and occasionally by having some scientists repeat the work of others. This is the method of science, rather than the list of steps found so commonly in introductory science texts and called the "scientific method." The shared principles and procedures of science have produced valid and reliable knowledge regarding the natural world that, in turn, has been used by engineers to improve the human condition, from the design of physical structures to the successful attack on disease and infirmity. It could be argued that this method of science is the most important contribution of science, extending even beyond

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Much of what occurs in both mathematics and mathematics instruction can be quite abstract, but the potential application in technology and engineering is vast.

the myriad discoveries produced by the application of the method itself.

Technology and Engineering and the National Mathematics Standards

Defining what mathematics is and what the focus of mathematics education should be has been a goal of the National Council of Teachers of Mathematics (NCTM) for several decades. This period of analysis and redefinition has caused mathematics education to shift away from the "back to basics" movement of the 1970s, which emphasized computational, skill-oriented proficiency, to the conceptual understanding and problem-solving focus of today. Interestingly, this shift in focus is similar to the transition of the skill-based endeavor of industrial arts education to the broader, more encompassing field of technology education with its problem-solving focus. Thus mathematics and mathematics education are poised to play an even more vital role in technological and engineering innovation than they may have previously.

The period of redefinition resulted in the landmark publication of the NCTM *Curriculum and Evaluation Standards* (1989), which made clear that being mathematically literate in a technological world required much more than computational proficiency. The *Standards* document called for students to be agile mathematical thinkers and problem solvers. To increase the mathematical power of students, it broadened the scope of elementary mathematics beyond the arithmetic focus to include algebraic reasoning, geometry, data analysis, and probability, better preparing students for a rich secondary mathematics curriculum.

The most recent document guiding mathematics education, *Principles and Standards for School Mathematics (Principles and Standards)* (NCTM, 2000), continues the trends started a decade earlier. The *Standards 2000* have a goal of producing students who not only know and understand mathematical content, but are skillful, perseverant problem solvers who can reason, conjecture, and justify their responses. To accentuate this important set of skills, the document separates mathematics standards into two categories: Content Standards and Process Standards. The utility of the Content Standards to the development of technology has long been appreciated with their topics of Number and Operations, Algebra, Geometry, Measurement, and Data Analysis and Probability. The Process Standards of Problem-Solving, Reasoning and Proof, Communication, Connections, and Representation may not sound like "mathematics" to those outside of mathematics education, but hold great potential for advancing technology education.

Curiously, although NCTM's *Principles and Standards* includes *instructional technology* as a guiding principle for learning mathematics, the idea that mathematics plays a dominant role in understanding and developing technology is not mentioned as clearly and explicitly as in the *National Science Education Standards*. It is clear, however, from an implicit perspective, that the NCTM standards are designed to foster the relationship between mathematics, engineering, and technology. In the section addressing mathematics for the scientific and technical community we find the following statement:

> *Although all careers require a foundation of mathematical knowledge, some are mathematics intensive. More students must pursue an educational path that will prepare them for lifelong work as mathematicians, statisticians, engineers, and scientists (NCTM, 2000, p. 4).*

NCTM's *Principles and Standards* does an excellent job of describing how we should teach mathematics, but does not venture beyond to suggest how we can help students understand how they can apply the mathematics that they are learning. Mathematics is a central discipline in supporting technology and engineering. Likewise, mathematics should have a dominant role in education in these subjects, but presently no specific direction is provided in the mathematics education standards for how students can apply mathematics in our highly technological and engineered world.

The Potential Role of Mathematics in Technology: Problem Solving, Reasoning, Representation, and Communication

In this section we will consider the role of the discipline of mathematics in engineering and technology as reflected in the national education standards guiding K-12 mathematics instruction. Several dominant themes include the nature of mathematics in problem solving, developing reasoning skills, and providing representations and models.

Mathematics Enhances Problem-Solving Skills

The most pervasive theme throughout the NCTM standards is that of learning mathematics through problem solving. Doing so enhances students' abilities as problem solvers and as effective mathematical thinkers. Students are encouraged to invent their own strategies for solving problems rather than follow a prescribed method offered by the teacher. Finding and sharing multiple strategies is encouraged. The process of solving the problem has become as important as the correct answer. With this type of classroom climate, students learn to be more resilient in the face of a wrong answer and know to try another approach if their first way did not work out. Students develop both confidence and perseverance as problem solvers.

The problem-solving skills gained through mathematics link clearly to engineering and technology, which at their cores are problem-focused disciplines. Identifying problems, exercising skills in addressing novel situations, and developing perseverance are all important characteristics that support the inventive and design-oriented spirit of technology and engineering.

Mathematics Requires Reasoning and Proof

Much of what occurs in both mathematics and mathematics instruction can be quite abstract, but the potential application in technology and engineering is vast. For instance, pure mathematics provides the tradition of the use of the formal proof in seeking mathematical truth. Analytical skills are developed as the "rules" of mathematics (the definitions, properties, postulates, and theorems) are applied in the construction of logical arguments. Even for the youngest learners, the math classroom is filled with talk of justifying one's answer as the teacher asks "how do you know that to be true" or "does this always work?" As students explain their solutions and justify their answers, they are encouraged to look for patterns and make generalizations. From picture-proof explanations to the use of inductive and deductive reasoning in both informal and formal proofs, math students learn to deliver a well-thought-out mathematical argument. The mathematics standards suggest, "People who reason and think analytically tend to note patterns, structure, or regularities in both real-world situations and symbolic objects; they ask if those patterns are accidental or if they occur for a reason; and they conjecture and prove" (NCTM, 2000, p. 56).

When we ask students to reason and conjecture with pure mathematical ideas, they are developing the skills of reasoning and conjecturing that can be used in other applications of life outside of pure mathematics. A question such as "What happens to the parabola if we add 6 to the equation?" may translate to "What happens to the potential speed of this vehicle if we change the kind of metal from which it is made?" As students become critical and logical thinkers in mathematics with a mind for discovering and justifying relationships, they likewise will gain tools necessary for defining and solving technological and engineering problems.

Mathematics Describes with Representation and Modeling

The NCTM standards use the term "representation" to refer to "process and to product—in other words, to the act of capturing a mathematical concept or relationship in some form and to the form itself" (NCTM, 2000, p. 67). From the simple direct modeling of "2 + 2 = 4" using counting blocks in kindergarten to writing and graphing equations that describe functional relationships, students learn to represent and model mathematical relationships in a variety of ways. Representing change is an important aspect of mathematics that is formalized in the study of calculus but occurs throughout the mathematics curriculum. For example, first graders chart the change of their heights over a school year. Middle school students discover that a constant rate of change makes a linear relationship and can be represented in a linear equation. In high school, motion is analyzed using computer simulation technology. Recognizing change and learning how to represent it is an essential skill that translates to understanding our technological world.

Even beyond the most basic forms of representation, mathematical models have a strong relationship with technology. The natural world is represented in the language of mathematics, resulting in models of the relationship between variables.

> *Mathematical models can be used to clarify and interpret phenomenon and to solve problems . . . One of the powerful aspects of mathematics is its use of abstraction – the stripping away by symbolization of some features of a problem that are not necessary for analysis, allowing the 'naked symbols' to be operated on easily. In many ways, this fact lies behind the power of mathematical applications and modeling (NCTM, 2000, p.69-70).*

Illustrating, testing, and tweaking relationships between variables in the process of modeling can permit engineers to test the limits of physical structures and explore relative efficiencies as part of the engineering process.

The Future of STEM Education: Authenticity Through Collaboration

In his engaging book on the process of engineering, Petroski (1984) stated that ". . . the essence of what engineering is and what engineers do is not common knowledge" (p. x). We would argue that this is the case across the STEM disciplines. We have a shared identity crisis, not only with members of the public, but also among practitioners and educators in science, technology, engineering, and mathematics. This lack of a common understanding of our shared goals and challenges can and should be the thread that ties us together as members of a single STEM community. The recent report, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (National Academy of Sciences, National Academy of Engineering, Institute of Medicine, 2007), makes the case clearly that all of the STEM disciplines must be involved in a new synergy to improve U.S. productivity, competitiveness, and ability to innovate by increasing the talent pool of individuals in the fields of science and technology.

Breaking Down the Walls, Building a STEM Community

In the classroom, students may learn about science, mathematics, and technology, but rarely do students learn what individuals in these fields actually do. Even more striking is the fact that students rarely experience anything of the work of those in the STEM fields. One of the reasons for this situation is the lack of authenticity in instruction that is caused, in part, by the rigidity of the discipline structure found in schools in which we teach the various school subjects in fairly discrete fashion. For instance, mathematics instruction has little involvement with school science in spite of the huge amount of interaction between these fields in the real world. Breaking down the walls between the STEM domains in school would make the study of these subjects more authentic and more applicable and interesting.

The development and maintenance of the discipline distinctions makes some sense; there are issues of expertise, history, commitment, knowledge, and even community associated with each domain of knowledge. Moreover, the disciplines have an identity because they represent distinct ways of knowing as defined by Phenix (1964) in his influential book *Realms of Meaning*. Included are empirics (science) and symbolics (mathematics) along with aesthetics (arts), ethics, and others. These various "schools of thought" have framed the curriculum for centuries, but there are increasing calls for a more interdisciplinary approach to teaching.

McComas (2009) cites advantages to interdisciplinarity in domains that relate to pedagogy (students are more motivated when their personal interests are served), practice (the work in school would look more like the world of work), and psychology (it is easier to see connections when the disciplines are presented together). Finally, there is the philosophical perspective, "giving learners an opportunity to view knowledge in a fuller, more holistic, and, ultimately, more authentic fashion [that] can be eye-opening, revealing, and intensely satisfying" (2008, p. 26). A more unified form of STEM education can change this reality. An increased focus on technology and engineering as the context for science and mathematics learning and vice versa could go far in addressing this situation. Scaling the walls that divide the STEM disciplines will offer new opportunities for interaction, exploration, expansion, invention, and understanding.

Tearing down the discipline walls is also implied in the frequently cited book *The World is Flat* by Thomas Friedman (2006). Friedman makes the compelling argument that—like it or not—many of the traditional impediments to communication and commerce have fallen in the past decade and a half. Dramatic weather in SE Asia can bring a financial storm to the rice commodity market in North America, and the decline in U.S. overseas purchases quickly causes economic upheaval in India in ways that look more like a flu pandemic than business. One of the major reasons to unify the STEM disciplines is that our existing education system simply does not function appropriately for the new world reality. The world may indeed be flat, but our educational system is as mountainous as ever. School disciplines are taught within the same silos that have been standing for the past century, with little attention paid to the fact that the world our high school graduates will enter has changed dramatically.

In the opening pages of the *57th Yearbook on Engineering and Technology Education*, Erekson and Custer (2008, p. 1) state ". . . it is clear that engineering education and technology education have the potential for a symbiotic alliance that will benefit both fields." We would add "science and mathematics education" to this view. Despite the call for a new alliance between the various STEM fields, a study of the perceptions of math, science, and technology education teachers toward technology education (Daugherty and Wicklein, 1993) suggests that there will likely be a bumpy road leading toward increased interdisciplinarity. The study showed that mathematics and science teachers were significantly less likely than technology education teachers to see the necessity of blending technology education within the mathematics and science curricula. Perhaps these views have changed in recent years, and science and mathematics teachers are taking more initiative to incorporate interdisciplinary lessons with opportunities for applications despite the pressure within their own discipline to concentrate on the standards that are the focus of benchmark testing.

A vital partnership between mathematics, science, and technology educators can only serve to strengthen the potential that each discipline offers the others. The instructional standards in these fields imply many suggestions for interaction, and we hope that future editions of all of these documents will go even further in acknowledging and supporting shared goals. An encouraging element of our call for increased collaboration may be found in the history of curriculum innovation. At the beginning of last century, John Dewey (1938) was one of the strongest advocates for project-based education strategies in which students explore a problem or phenomenon using tools from various disciplines. Such an approach should be reconsidered even though the challenges of getting teachers to work together can be daunting.

Perhaps it is time for a new and strategic alliance between the individual STEM elements. Such an alliance can and should recognize the kind of obligate symbiosis that we know exists between the STEM fields. Such an understanding would strengthen education within and between each of the STEM fields and would better prepare students for the challenges and opportunities of our ever-flattening world.

It might be useful to examine the possibility of what could be called "asynchronous project-based education" in which the students, rather than the teachers, take primary responsibility for putting it all together. Rather than insist that the project approach change classroom instruction dramatically, with everyone on problems at the same time across various STEM classes, the needs of the problem would cause students to seek assistance from various instructors when such expertise is required. This is more like the science fair or engineering competition approach in which only one teacher takes the lead in organizing the projects and setting deadlines, but the students get assistance as needed. Instruction goes on in the typical fashion in each of the STEM classes, but the demands of the project help to bring the disciplines together for any particular student.

Another way to blend the STEM disciplines is for one discipline to provide data for analysis in another. The easiest way to conceptualize this is to consider the example of students gathering data in physical science class, for instance, that would later be analyzed and manipulated in mathematics class. This is a more "synchronous" approach and one that does require some interaction between instructors. In such cases, the data and the ultimate analysis of these data are much more authentic than is typical. In the end result, an alliance between STEM teachers would serve each discipline effectively. Perhaps the answer to the age-old question from students, "When are we ever going to use this?" could be addressed by looking at the Science and Mathematics Content and Process Standards to find the "*this and how*" with the "*when*" provided in the technology education standards.

We will conclude by reconsidering the biological metaphor of symbiosis proposed by Erekson and Custer in their statement about the relationship between technology and engineering. Their choice of this term is apt, but perhaps there is an even more accurate expression to describe the desired state between the various STEM fields. In biology there exist partnerships of organisms that are so tightly interwoven that none of the partners can be separated from the others. This relationship is called obligate mutualism. We would argue that the four partners in STEM education—science, technology, engineering, and mathematics—really are parts of an obligate association. This is true

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even if those who advocate for the maintenance of the traditional disciplines disagree. Perhaps it is time for a new and strategic alliance between the individual STEM elements. Such an alliance can and should recognize the kind of obligate symbiosis that we know exists between the STEM fields. Such an understanding would strengthen education within and between each of the STEM fields and would better prepare students for the challenges and opportunities of our ever-flattening world.

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Chapter 5

Technology and Engineering Programs in Action

The previous sections of this document have considered the important components of a STEM education, with a specific emphasis on the "T" and "E." The success of technology and engineering teachers becomes evident when teachers are given the support and an opportunity to place this curriculum thrust into action. Enthusiastic teachers throughout the profession have pioneered innovative techniques in the implementation of their programs.

The following teachers were selected to describe and share their work with the reader. In almost every situation, these teachers are joined by colleagues in their departments or schools whom they readily recognize as important contributors to their efforts.

The contributors are:

Krista Jones
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Enthusiastic teachers throughout the profession have pioneered innovative techniques in the implementation of their programs.

TECH…
Not just a class – A way of thinking

Bellevue Elementary School
Bellevue, Idaho

Technology education is all about teaching and using practical reasoning to explore and shape our world. Oh sure, we use lots of cool techno-gadgets and engineering and scientific equipment. However, these are only tools to aid and guide us through our exciting problem-solving adventure called life!

For Bellevue Elementary, our technological adventure began about 16 years ago. Parents in our community banded together with the desire for more hands-on, real-world scientific learning for their children. Our Blaine County School District obliged, and what began as a PTA-funded science enrichment class has evolved into an amazing District-wide, pre-school through eighth grade standards-based, award-winning technology education program.

We are fortunate to have one middle school and four elementary technology education programs in our school district; and boy do we have fun! Each program is standards-based, but is as unique as its students and instructors! Because technology education is dynamic in nature, as instructors we are able to weave the core curriculum through not only the students' expertise and learning passions, but our own.

For example, our Wood River Middle School instructors Jeremy Silvis and Al Amato focus on student-led projects like sterling engines, parabolic trough solar cookers, and lawn chair manufacturing. Their students just completed a full-scale, drivable sustainable electric vehicle that was featured in *Sun Valley Magazine*! Hemingway Elementary's Scott Slonim takes his students on a journey through designing and constructing toys and playground equipment of the future. His students have become accomplished videographers as they produce award-winning commercials and a daily live closed-circuit television show. Mary Ann Ward at Woodside Elementary encourages her students to become environmental technologists by designing alternative energy technologies, culminating with an annual alternative energy fair. At Hailey Elementary, Chris Nelson takes

Robotic programming and docking of our BESTECH foam shuttles.

BESTECH Girls Constructing a Trebuchet.

BESTECH boys enjoy a NASA visit.

BESTECH C.S.I.

her students to Mars for driving lessons! Her students design and construct LEGO® Mindstorm rovers, build a faux Mars terrain, then compete to see who makes it through the Martian Mile!

At Bellevue Elementary, my focus is connecting everything to the real world. Our projects are ever changing, triggered by current events and student interests. We also involve a great deal of outside expertise such as NASA, the Idaho National Laboratory, Educational Resource Center, and various community members. Each one of these expert encounters gives the students another view of the importance of technology, engineering, math, and science. An example of one such encounter was when astronaut Barbara Morgan went to space—we were there! Well almost—I took some of our fifth graders to speak live with the STS-118 astronauts while they were aboard the International Space Station! What an experience for us all! Then later in the year, we were able to have a personal sit-in with Barbara and present her with our completed space basil flowing growth chambers. She was tickled! NASA is a big partner at Bellevue. Our students even partake in an in-class, intense, simulated astronaut training camp! This year we're building a lunar colony, complete with a Lunar news video documentary!

Some of our other event-triggered projects have been to raise money for the war orphans of Iraq, the disaster victims of the Tsunami, and Hurricane Katrina. Each of these projects involved designing, manufacturing, marketing, and selling products such as Techno-Treats Chocolates, Tsunami heart pendants, and kid recorded musical CDs. Projects like these show the students the impact their knowledge and skills can have on a huge scale.

Other favorite projects include design and construction from junk—such as building working trebuchets, wheelbarrows, and inventions. In fact, one second grader's invention was purchased by Pitsco and is now a top seller! Other projects, like our latest Crime Scene Investigation, are completely student driven. What started as an April Fool's joke on my students, ended with the county police running a full investigation and teaching us about fingerprinting, forensics, and biotechnology!

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Although all of our programs have a different focus, our mission is the same: To immerse our students in experiences that make lifelong impacts.

That's lifelong learning! That's Technology Education!

Krista Jones
Bellevue Elementary School
www.blaineschools.org/Schools/Bellevue/tech/bestech.html

Integrating Children's Engineering Into the School's Curriculum

J. B. Watkins Elementary School
Chesterfield County, Virginia

"This isn't your father's classroom; heck, it's not even my classroom! J.B. Watkins is light years ahead of the textbook-based classrooms in which I grew up," exclaimed an excited dad after visiting his daughter's first-grade class during a Children's Engineering activity. Sentiments such as the one above clearly define the intent and content of the Children's Engineering and Design Technology focus at J.B. Watkins Elementary School in Chesterfield County, Virginia.

Four years ago, we began the exciting journey of enriching the curriculum for students in a unique and fun way. It began by first enticing teachers to enroll in a graduate course—Technology Workshop: Children's Engineering—that was offered on our school campus through James Madison University. Excited by what they learned and anxious to try out this new learning with their own students, a new era at J.B. Watkins was born. From kindergarten to fifth grade, students were extending their learning by engaging in hands-on technology activities. Through such engagement, students' knowledge of the core content is cemented across the curriculum in an authentic, integrated manner.

It is our school's mission to prepare our students to compete and succeed in today's global society and to face the challenges of the 21st Century by arming them with vital lifelong skills. Children's Engineering

Students at J. B. Watkins Elementary School learning lifelong skills.

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promotes such skills as problem solving, critical and creative thinking, collaboration, and communication. Each year, we are constantly amazed at the sophistication of the student products, the elevated confidence levels of our students, and their ability to successfully collaborate in small groups as early as the first grade.

The J.B. Watkins' parents have supported this initiative by furnishing the classrooms with materials and supplies necessary for designing products. Parents and teachers' spouses with engineering interests volunteer and share their knowledge in the classroom. One of the neighboring high schools has partnered with us and periodically provides us with willing engineering students who volunteer their time and skills during T & E activities.

For our school's enduring focus on technology education, J.B. Watkins received Virginia's Program Excellence Award and was honored at the 2007 International Technology Education Association Conference. Since then several of our teachers have submitted STEM articles for publication, have applied and received technology grants, presented at local and national conferences, and one has been awarded the Elementary Technology Teacher Excellence Award for the state of Virginia. At the 2009 ITEA conference in Louisville, Kentucky, one of our stellar teachers was awarded the Mary Margaret Scobey award for demonstrated dedication to elementary school technology education. Yet another of our outstanding educators is now an adjunct instructor at James Madison University, teaching the technology education graduate course to teachers. Since the fall of 2005, the graduate course has been offered 11 times in our district, and to date 143 teachers have completed the course.

Without the unwavering support of our superintendents, directors of instruction, TECC Director Ginger Whiting, and forward-thinking teachers, none of J.B. Watkins' successes could have been possible. The program is supported by an in-school committee of teachers and administrators meeting once per month, sharing and discussing grant ideas, teaching suggestions, research articles, conference information, and websites to help keep our school's vision in the forefront. This committee, along with our school's science committee and parents, coordinate and implement an annual Science and Engineering Extravaganza that is the envy of the school district. This is another opportunity to share with the community samples of our students' work and offer parents opportunities to experience Children's Engineering firsthand.

What started out as one principal's desire to add rigor and relevance to the existing curriculum while preparing students to be self-directed learners equipped with 21st Century skills has yielded unintended and most rewarding consequences.

Marlene C. Scott,
J. B. Watkins Elementary School

STEM Provides Students the EXPERIENCE Base

Pittsburg Community Middle School
Pittsburg KS

PCMS Technology Education continues to focus on providing the environment and STEM activities for its students in Science and Technology classes. In 1995, the science and technology classes combined into year-long classes. Grades 6 through 8 are team-taught by certified science and technology teachers to ensure that core concepts are taught.

With the goal to make STEM activities more transparent, PCMS staff took another major step in 2004, with the addition of a three-story wing added to the main campus. The Science, Technology, and Mathematics classrooms and laboratory are interconnected. At the center of each floor is a 50-student tiered seating learning center. This configuration supports interdisciplinary team teaching and flexibility. Students can walk to any lab via this central classroom without going into the hallway.

This facility allows flexibility. Teachers are able to deliver lessons in large or small groups at any time or respond to immediate student needs. For example, orientation can be done in large group, or a few students might go to a lab for small-group lessons. This grouping creates a "2 for 1" time savings. In other words, a les-

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son taking ten classes to complete in a single classroom now only takes five days in the larger learning center. Typically each class gains an additional 15 to 20 class periods each year. This facility allows teachers to teach more in less time.

The district has supported the program by assuring that the instructional and lab equipment remains current. The 2-to-1 computer ratio allows students and teachers the ability to deliver instructional content quickly.

To keep the labs from becoming routine, each grade level employs different styles and timelines for the delivery of content and projects. A mix of vendor and teacher-created lessons challenge both teacher and student.

In addition to teacher and larger group lessons, Grade 6 uses two- and four-person cooperative labs three days each. During the year, students will have completed over 30 labs. Grade 7 delivers content in two-person cooperative learning, with students completing 14 seven-day labs. Grade 8 labs vary the delivery methods and timelines, employing single, two- four- or six-person labs.

The Car Crash unit is a typical STEM lesson. This unit touches students on an emotional and educationally important topic. Some of the highlights of this lesson are:

- Review the history of car design.
- Learn how Newton's laws apply to the crash.
- Compute the impact forces of a crash using variables.
- Understand the relationship of friction and tires.
- Discuss statistics from local, state, and national DOT databases and their relationship to lawmaking.
- Create a PowerPoint® presentation comparing the crashworthiness of two vehicles of similar weight as determined by frontal- and side-impact testing data.
- Create a model vehicle for destructive crash testing.

The final exam consists of a letter written by the students to parents describing several key terms, concepts, the application of the lesson to their lives,

To keep the labs from becoming routine, each grade level at Pittsburg Community Middle School employs different styles and timelines for the delivery of content and projects.

and how the lesson can impact their driving habits and those of other drivers. These letters serve as part of the summative data.

Students at PCMS are encouraged to participate in the Technology Student Association (TSA) and Science Olympiad as well as to conduct their own independent research.

Community and parental involvement is facilitated through Parent Night and the annual Sci/Tech Exposition. Parent Night allows students to bring an adult "back to school" and complete a favorite activity demonstrating what they've learned. The Expo is the largest event held at our school. Students show completed independent and team-created science and technology investigations and projects. Students test projects and race cars with the public looking on. TSA students recreate the State TSA Problem-Solving event with an adult as their partner.

Staff members are: Science – Larry Downing, Pam Baldridge, and Mel Anderson; and Technology – Tom Zerr, Greg Lopez, and Larry Dunekack.

Tom Zerr
Pittsburg Community Middle School

What is Engineering Your Future?

Princeton High School
Cincinnati, Ohio

The need to focus on effective science, technology, engineering, and mathematics (STEM) education is increasingly recognized as an urgent national priority. As reported by the congressional STEM Caucus, STEM disciplines are responsible for providing:

- Scientists and engineers to carry on research and development that is key to our economic growth.
- A workforce capable of dealing with the demands of a science-based, high-technology economy.
- Technologically literate citizens who can make appropriate decisions regarding public policy.

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While there is an urgent need to ensure the adequacy of the U.S. science and engineering workforce, college enrollment in STEM disciplines is flat, particularly for women and minorities.

Many high school students choose not to pursue STEM disciplines due to a number of factors, including:
- Lack of understanding of the nature of STEM opportunities.
- Perception of STEM careers as less relevant to society than medical or business careers.
- Perceived difficulty of the programs of study.

Engineering Your Future is a new course being developed at Princeton High School to introduce students to the field of engineering. Over a one-year period, my students will be working in cooperation with the University of Cincinnati College of Engineering, discovering what engineering is. They will learn what the engineering design process is, work in teams to solve open-ended projects, and present their projects to the class. UC professors will be lecturing as students watch the lectures via podcasting or from a streaming video on the UC website. This will be their homework, along with some reading from the textbook. Class time will be primarily used for lab work. The course is a two-semester sequence. The first semester can be taken without taking the second semester. The prerequisites for this course are: algebra, geometry, and two years of college-prep science.

Engineering Your Future will introduce students to a wide range of engineering and technology disciplines and present fundamental engineering principles so that students can begin to perform engineering calculations. Topics that span all disciplines, such as problem-solving strategies, technical communication, and impacts of technology on society, will also be presented.

The primary delivery method for the class will be hands-on labs. I am integrating the math and science concepts they have learned into these labs. I try to coordinate my labs with the science and math teachers, so when they teach a concept, I will reinforce it with an integrated project. My students will see how to apply the science and math concepts into projects using the engineering design process.

Students at Princeton High School learning about buoyancy and electromagnetism through the Underwater Remotely Operated Vehicle project.

We are teaching this class "through" a vocation, not "about" one. Several of our labs have been written up in *The Technology Teacher* and *NSTA Reports*. One lab I developed was on answering the question "How many licks does it take to get to the center of a Tootsie Roll Pop?" Students study the science of gears and gear ratios, then they have to create a machine using gears to count the number of licks it takes to get to the center of a Tootsie Roll Pop. The students voted this project their favorite. The President of Tootsie Roll read the article and called me twice regarding the project. She thought it was so good, she is supporting the project by sending me 1000 Tootsie Rolls each year so my students can experiment with their machines.

Another project gaining attention is my Underwater Remotely Operated Vehicle—which was described in *The Technology Teacher* in 2009 and on the National Science Teachers Association website in 2008. Students have to study the history of underwater devices and then design a machine to be operated in our pool. The ROV has to pick up washers at the bottom of the pool using an electromagnet. The math and science that students learn with this project are buoyancy and electromagnetism. They must wind their own electromagnet and get it strong enough to pick up a washer at the bottom of our pool. We are integrating TRIZ into this design process by using an interactive Internet site. Students will use the TRIZ site to help them with their invention. They will be keeping a journal as they work their way through the project.

Princeton has worked with regional industries to provide the students opportunities to visit these organizations, shadow professionals, and if possible, utilize appropriate facilities for some of the learning activities. My students went to General Mills for a visit and then their engineers came to Princeton to help with a project that was designed by General Mills for Princeton. My students had three weeks to come up with an answer and present their findings to the plant manager and plant engineers. Other projects the students work on throughout the year will help them learn teamwork and communication skills.

Some of the unique features of the class include:

- The class is honors-level weighted.
- In-class time is devoted to projects, discussions, and problem solving.
- Homework will mostly be viewing lectures via the web and/or podcasting, with some book reading.
- College credit will be awarded to students who attend the University of Cincinnati.
- This class is targeted to juniors and seniors in college-preparatory tracks.

Engineering Your Future is a collaborative effort between Princeton High School and the University of Cincinnati. Seven other area high schools are currently teaching the class. In the school year 2009-10, we will be gaining at least one school from the Akron area. Teachers in the Cincinnati area meet at least once a month to talk about successes and problems. We are in constant email contact and help each other with test questions, rubrics, and lab development. Any information written by one member is shared with all members. Information is available at www.eng.uc.edu/eet.

Brian Lien
Princeton High School

Making the Seemingly Impossible, Possible Through Technology and Engineering Education

Greenfield-Central High School
Greenfield, Indiana

Greenfield-Central High School is a secondary school (1400 students, Grades 9-12) located in Greenfield, Indiana, 20 miles east of Indianapolis in a population center of 12,500 residents.

The Greenfield-Central Technology and Engineering program consists of fourteen technology education course selections and eight engineering courses. Seven instructional and laboratory facilities support these courses. Available technology education courses include a series of systems courses dealing with communication, construction, manufacturing, and transportation. A similar series of courses focuses on processes of these four areas. Other course titles include technology systems, technology and society, enterprise, design processes, fundamentals of engineering, and computers in design and production systems. Each course has an extensive outline and description that supports its title and intent.

The Engineering STEM Academy courses are taught using a multidepartmental approach. Greenfield-Central High School teachers from the Technology, Math, Science, and Physics departments work together as a team, teaching students to explore and learn about the engineering professions. In the fall of 2010 a new 2000-square-foot, state-of-the-art STEM classroom/ laboratory will open, thus providing new opportunities for students and teachers.

Greenfield-Central High School students have communicated with the International Space Station via their HAM radio sets. Advanced Manufacturing courses make full use of the production facilities. Communication and construction activities are conducted in the technology and engineering education department and in the community. The facility provides an exceptional learning environment for all students. Administrators and teachers from across the region come to the school for tours and to see "how" to implement technology and engineering education, plus "learn" how the Interdepartmental STEM Academy could work in their school.

After-school student competitions are an important component for the application of STEM principles at Greenfield-Central High School. Engineers, parents, and community stakeholders partner with teachers to ensure that students are given the opportunity to gain application skills not available during the structure of the school day. This partnership strengthens the connection with the school program and the community.

Two major STEM competitions at which Greenfield-Central students have excelled are the Indiana Super Mileage Challenge and statewide VEX Robotics Competitions.

With the help of local engineers and teachers, the Indiana Super Mileage Challenge teaches the students to apply the concepts of math, science, and engineering to a real-world setting. Greenfield-Central High School students have competed in the competition since the 1990s, and are consistently one of the most successful

Greenfield-Central students building their Super Mileage vehicle...

...and designing a building.

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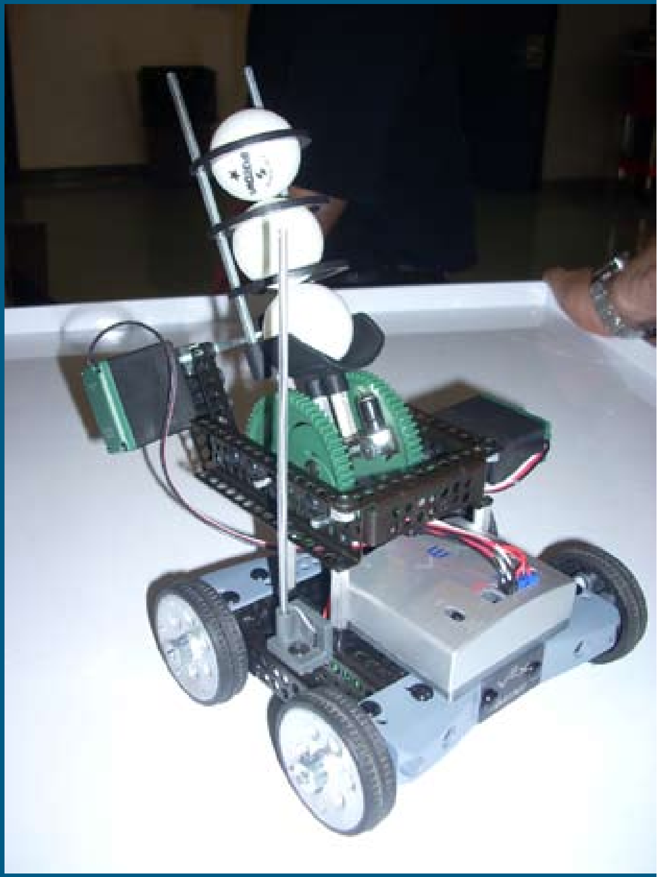
Greenfield -Central students watch the Vex competition.



Example of a Vex robot

competitors. They have won the event twice, with fuel mileage exceeding 1000 mpg.

On May 2-3, 2008 G-CHS students competed at the Inaugural VEX Robotics World Championship Competiton playing the game "Bridge Battle" at California State University, Northridge. VEX Robotics Competitions give students hands-on tools to enhance their STEM education. The Bridge Battle game provided students with a fun and challenging robotics competition.

Greenfield-Central's Technology and Engineering instructors are: Gary Wynn, DTE, Technology\Department Chair; Mark Holzhausen, Technology\STEM Academy Lead Teacher; Trent Taylor, Technology\STEM Academy; John Rihm, Science\STEM Academy; Tom Elsworth, Physics\STEM Academy; Nick Fishel, Math\STEM Academy; Angela Crumlin, Math\STEM Academy.

Gary Wynn, DTE,
Greenfield-Central High School

Project-Based Technology Program

Cody High School
Cody, Wyoming

The Project-based Technology Program (PBT) at Cody High School resides in facilities collaboratively designed and built in 2007-2008. Lab areas for Vocational Agriculture, Woods—Power Technology and Manufacturing, Computer-Assisted Manufacturing—Materials Testing, Robotics and Design Technologies, and Computer-Based Drafting and Architectural Design, are located in a high-traffic/high-visibility section of the school.

The emerging PBT program currently has classes that expose students to automated design and manufacturing processes. An engineering strand of the program exposes students to Global Positioning Systems, Engineering Surveying, and Geographic Information Systems.

Cody staff members from the science, agriculture, technology and career education areas are currently working with the local Northwest Community College, EnXco Wind Power and Energy, and AET Wind Power to create an Energy Pathway program accessible to students upon graduation from high school. This exciting and emerging program dynamic will introduce energy education into Grades K–8. At the high school level, existing and future program elements will have students actively explore wind power, solar energy, biofuels, carbon sequestration and clean coal technology. All of these elements show promising employment growth within the state of Wyoming.

Students will soon design, develop (with CNC machine tool technology), and test vertical and horizontal wind turbines, crush seeds to produce biodiesel fuels, test and do analysis on biodiesel in small diesel engines, and meter and study small residential solar installations. Plans are underway to install residential-sized wind and solar arrays behind the PBT lab at Cody High School.

Lemuel "Chip" Miller, DTE
Cody High School

This exciting and emerging program dynamic will introduce energy education into Grades K–8 in Cody, Wyoming.

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Chapter 6

STEM Education Resources: The Short List

Sharon A. Brusic
Millersville University of Pennsylvania

There is no shortage of resources available related to Science, Technology, Engineering, and Mathematics (STEM) Education. However, the vast majority focus primarily on one or two slices of the STEM acronym rather than addressing all as a cohesive whole. That said, there are still many great resources that will contribute to a better understanding of STEM education.

It was no small task to try to identify the key STEM resources for educators, especially given the abundance of materials currently available. The compilation that follows is an attempt to highlight some of the essential STEM-related documents for today's educators, especially those pertinent to the technology education field. The decisions about which items to include were not made hastily. There was an attempt to include a range of resources that would appeal to K-12 teachers, administrators, supervisors, and other educational leaders. Moreover, only resources that were easily accessible were considered. Hence, there were many excellent papers presented at conferences that were noteworthy, but they would not be easily found by most readers of this document, so they were not included. Since websites are highly transitory, sources accessible only on the Web were not considered, with one exception. This document was deemed highly significant to this compilation and reliable in terms of its web address.

These resources are organized into three categories. The Call for STEM section includes documents that address the need for STEM education or which emphasize important aspects of STEM education. The STEM Education Standards and Guidelines section lists standards documents supportive of STEM education, as well as other resources that can guide and inform curriculum development. The STEM Perspectives and Implementation section includes articles that present interesting and informative viewpoints on STEM education, as well as a few of the many curriculum materials that stand out as meaningful attempts to address one or more areas of STEM in K-12 classrooms.

There is no shortage of resources related to Science, Technology, Engineering, and Mathematics (STEM) Education. However, the vast majority focus primarily on one or two slices of the STEM acronym rather than addressing all as a cohesive whole.

A Call for STEM Education

Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology, National Academy of Sciences, National Academy of Engineering, Institute of Medicine. (2007). ***Rising above the gathering storm: Energizing and employing America for a brighter economic future.*** Washington, DC: National Academies Press.

This report is based on a study undertaken to address concerns about globalization and America's readiness to compete as a science and technology leader. In addition to presenting and discussing the issues, the committee offers four recommendations for addressing the concerns. Two of these recommendations have implications for STEM education. The first one calls for improving K-12 science and mathematics education with a goal of getting more students to pursue rigorous science, mathematics, and engineering degrees in college. A second recommendation pertains specifically to higher education with the need to recruit and retain the brightest and most innovative students, scientists, and engineers. All recommendations include action items that could make these goals achievable with the necessary support and funding.

National Science Board. (2007). ***National action plan*** for addressing the critical needs of the U.S. science, technology, engineering, and mathematics education system. Arlington, VA: National Science Foundation.

The National Science Board (NSB) is appointed by the President of the United States. In addition to serving as the policymaking body of the National Science Foundation, it is responsible for advising the President and Congress about national science and engineering policy. This NSB report presents a detailed action plan for making significant and measureable improvements in the Nation's STEM education system. It is a must-read for anyone who wants to fully understand the need for STEM education, the steps that experts in these areas recommend to ensure that all American students receive a quality STEM education, and that there is a highly qualified teaching workforce to make it happen.

Technology and engineering education taught here...

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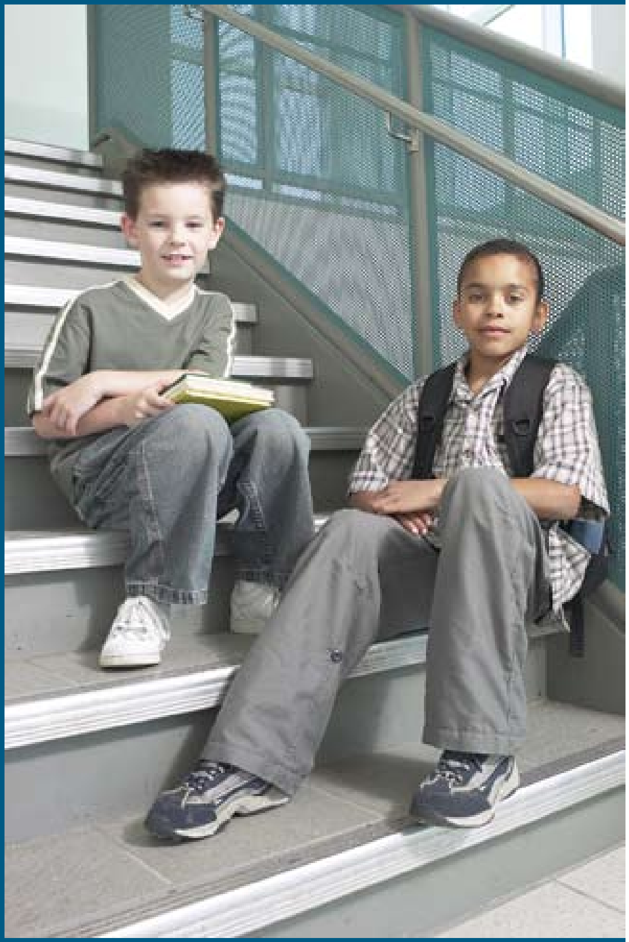

Pearson, G. & Young, A. T. (Eds.). (2002). ***Technically speaking: Why all Americans need to know more about technology.*** Washington, DC: National Academy Press.

This report is the result of a two-year study by a committee operating under the auspices of the National Academy of Engineering and the National Research Council Center for Education. It is a good resource for gaining some clarity on technological literacy—what it is, why it is needed, and what is needed in order to improve it. The report appendix, Toolkit for Technological Literacy, includes a helpful, annotated list of resources for learning more about technology and technological literacy.

Rutherford, F. J. & Ahlgren, A. (1990). ***Science for all Americans*** (2nd ed.). New York: Oxford University Press.

This seminal document lays the foundation for STEM-related efforts by identifying understandings and ways of thinking that are essential in a world shaped by science and technology. It makes a strong argument for educational reform in order to enable individuals to achieve science literacy, which includes natural science, social science, mathematics, and technology. It provides a thorough overview of the nature of each of these "human enterprises" and includes common themes and habits of mind that are central to developing science literacy.

STEM Education Standards and Guidelines

American Association for the Advancement of Science (AAAS). (1993). ***Benchmarks for science literacy*** (Project 2061). New York: Oxford University Press.

Benchmarks for Science Literacy is an important document that corresponds with the Science for All Americans report. In this volume, educators are given guidelines about what individuals should know and be able to do by Grades 2, 5, 8, and 12 across each area of science, mathematics, and technology. These Benchmarks can serve as a starting point for curriculum developers and would be helpful to anyone developing

STEM-related curricula. The Benchmarks are the result of extensive collaboration among educators and are grounded in research on learning.

American Association for the Advancement of Science (AAAS). (2001). ***Atlas of science literacy (Project 2061), Volume 1.*** Washington, DC: Author.

American Association for the Advancement of Science (AAAS). (2007). ***Atlas of science literacy (Project 2061), Volume 2.*** Washington, DC: Author.

This two-volume series is a unique and valuable tool for STEM educators and curriculum developers. Using a large-scale, spiral-bound book format (12"x15"), together these atlases graphically show the connections between all of the Benchmarks for Science Literacy (AAAS, 1993) across each of the grade level bands from K-12. Known as "strand maps," these graphic depictions enable readers to visualize how students can build deeper understandings of science, mathematics, and technology over time by seeing the interrelatedness of concepts. Every strand map is accompanied by notes that bring clarity to the ideas and information, thus enabling readers to more fully understand the content and see how all the pieces fit together like a huge puzzle. In addition, there are brief discussions of pertinent research for many of the topics that help to validate the information and guide readers to more information, if desired.

International Technology Education Association. (2000/2002/2007). ***Standards for technological literacy: Content for the study of technology.*** Reston, VA: Author.

Through the Technology for All Americans Project, the International Technology Education Association (ITEA) developed twenty standards aimed at addressing students' technological literacy in Grades K-12. All of these standards, including benchmarks for students in Grades K-2, 3-5, 6-8, and 9-12, are presented and described in this document, which has many direct and indirect connections to science, engineering, and mathematics education. In the absence of STEM standards, this document is an especially critical resource for every technology educator seeking to develop STEM-related curricula.

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

This document, which expands upon the 1989 mathematics standards, provides a comprehensive overview of mathematics standards, with expectations presented in four grade bands: Pre-kindergarten (PK)- 2, 3-5, 6-8, and 9-12. This is an excellent resource for educators in order to develop a thorough understanding of both mathematics content (number and operations, algebra, geometry, measurement, and data analysis and probability) and process standards (problem solving, reasoning and proof, communication, connections, and representations).

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

National Science Education Standards spells out what needs to happen in order for scientific literacy to be achieved in our nation. Six different sets of standards are presented, including standards for science teaching, professional development for teachers of science, assessment in science education, science content (Grades K-12), science education programs, and science education systems. The Science Standards give some attention to building students' understanding of technology as well.

STEM Perspectives and Implementation

Berry, R. Q., Reed, P.A., Ritz, J. M., Lin, C.Y., Hsiung, S., & Frazier, W. (2005, December/January). ***STEM initiatives: Stimulating students to improve science and mathematics achievement.*** *The Technology Teacher, 64*(4), 23-29.

The authors discuss the value of using a "contextual engineering environment" and collaboration between math, science, and technology education in order to help students to build STEM competencies. They use concept mapping to demonstrate how connections can be made between subjects using standards from earth science, algebra, and a foundations of technology course as an example. A detailed STEM activity is presented to demonstrate how science, technology, and math concepts can be meaningfully learned through an engineering project related to earthquake simulation.

Hacker, M. & Burghardt, D. (2008, November). ***Addressing issues related to technology and engineering.*** *The Technology Teacher, 68*(3), 28-33.

Michael Hacker and David Burghardt codirect Hofstra University's Center for Technological Literacy, and they have conducted numerous large-scale projects in STEM-related areas. In this published interview, they share some interesting insights, including a summary of some of their research findings comparing technology with engineering, the use of an "Informed Design" paradigm, and their perspectives on technology education's role in STEM education.

Kirkwood, J. & Foster, P. (1997). ***Elementary school technology education.*** (46th Yearbook of the Council on Technology Teacher Education). New York: Glencoe McGraw-Hill.

Long before the STEM acronym took hold in the media, there were efforts underway to promote the integrative study of subjects. This is particularly true at the elementary level, which is often overlooked when STEM education is discussed. This CTTE Yearbook focuses upon the value of technology education in the elementary grades as a way to help children see the interconnectedness of subjects and to make sense of their world. Of particular interest here is a chapter specifically dedicated to Mathematics, Science, and Technology (Chapter 3). But, readers should not skip a few other chapters that enable one to get a good sense of the bigger issues surrounding integrative technology education in Grades K-6—such as Chapter 6 (Engaging the Senses in a Quest for Meaning) and Chapter 7 (A New Paradigm for Schooling).

LaPorte, J. & Sanders, M. (1996). ***Technology science mathematics: Connection activities, teacher's resource binder.*** New York: Glencoe/McGraw Hill.

This 400-page binder includes six well-developed and field-tested middle school activities prepared through a National Science Foundation-funded project. Although the document is now more than a decade old, the ideas fit perfectly within today's STEM education curriculum efforts. Each activity includes all of the pertinent technology, math, and science concepts as well as implementation suggestions to enable teachers to collaborate and effectively integrate concepts to enhance students' learning through a hands-on approach.

Litowitz, L. S., Warner, S., Burghardt, D., Hacker, M., Havice, W. L., Clark, A. C., & Welty, K. (2008, July 15). ***Understanding the T&E in "STEM."*** Proceedings of the 2009 Hawaii International Conference on Education (pp. 2946-2982). Honolulu, HI. Retrieved (n.d.), from www.hiceducation.org/EDU2009.pdf.

This document includes six separate papers presented as part of a panel presentation. Together these manuscripts provide readers with an excellent overview of what technology education is (and is not). There is an informative explanation of technology and engineering from some different viewpoints. And, Welty's contribution on Curricula for Technology & Engineering provides a succinct and valuable overview of 18 different curriculum initiatives (Engineering is Elementary, Project Lead the Way, A World in Motion, City Technology, I^3 (Invention, Innovation, and Inquiry), and many others) that can be used to support STEM-related programs from elementary through high school levels. This section should not be missed since it provides a succinct overview of important curriculum efforts and website addresses for those who desire to seek more information.

Sanders, M. (2009, December/January). ***Integrative STEM education: Primer.*** *The Technology Teacher, 68*(4), 20-26.

Mark Sanders' article presents readers with an overview of the Science, Technology, Engineering, and Math (STEM) movement. Moreover, he makes a strong argument for advancing integrative STEM education that will more effectively make the much-needed connections between science, technology, engineering, and math.

Thompson, J. & Fitzgerald, M. (2006, September). **Super Mileage Challenge: Combining education and fun!** *The Technology Teacher, 66*(1), 31-33.

The authors describe an exciting and successful contest called the IMSTEA Super Mileage Challenge (SMC). IMSTEA is the Indiana Mathematics, Science and Technology Education Alliance and it sponsors the event as part of an effort to improve literacy and competency in math, science, and technology. The SMC engages high school student teams in designing, building, and testing the most efficient single-person vehicle powered by a one-cylinder, four-cycle engine. The challenge promotes students' STEM understandings through practical and meaningful activity and provides one clear example of a successful STEM project for students.

Trotter, A. (2008, March 27). **A school where STEM is king.** *Education Week, 27*(30), 24-26.

Learn more about a Baltimore school that focuses on STEM education and promoting students' ingenuity. This specialized high school places great emphasis on interdisciplinary learning and touts a challenging curriculum that engages learners in intensive research, problem-solving, and creative real-world experiences that prepare them to excel in STEM-related studies and careers upon graduation.

2009 Super Mileage Challenge

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Chapter 7

A STEM Call to Action

Kendall N. Starkweather, DTE
International Technology Education Association

With the rapid advances in technology and the plethora of changes in society that involve new, life-changing inventions, education has had to attempt to keep pace. Technology and engineering must become a part of the "new basic" in our next generation of general education for all students. Societal members are being made aware of advances in thinking that allows human ingenuity and technology to be used in the solution of problems facing our world today.

Take this opportunity to gain a better understanding of the need for STEM education and its critical role in creating a technologically literate society in which individuals use their thinking skills to fulfill human wants and needs. The rationale for the "T" and "E" has been specifically addressed in order to gain support for these subjects as part of the overall STEM effort. Technology and engineering have proven to be critical components in solving societal problems. Alone, science and mathematics fall short of allowing students to truly implement the knowledge necessary to make a better society.

The following are ways that the concerned citizen can help make such an education a reality. Join dedicated and engaged colleagues from across the country who strive to make a difference in an education for the next generation.

Parents

Don't settle for less than the best education for your child at any age level. If your child likes to make or create and seems technologically inclined in any way, have him or her explore these courses. Technology and engineering are for students who envision themselves as architects, high-tech workers, technicians, and more. These experiences or courses are not limited only to future engineers! Technology and engineering can and should be taught from the earliest grades through the university level. Knowledge about science and mathematics alone does not provide the full experience necessary to make an inventor or creator. The teaching solution does not have to be an expensive facility with constant upgrades that are a burden on a school's finances. Examine your options; seek information about programs already making a difference in communities across the United States; request that your administrators become informed about opportunities to make technology and engineering a meaningful

We must count on technology and engineering teachers and their students' imaginations to help us meet the needs of the 21st Century.

part of a STEM education. A technology and engineering education is a sound investment for all students, but currently gets very little support.

School Administrators/ Boards of Education

Our school leaders have a legal responsibility to assure that a curriculum prepares students to live effectively in today's technological society. However, more is needed. Such an education creates opportunities for the student who wants to explore STEM options, enabling them to design, invent, and innovate. School leaders are the curriculum leaders who can help in the search for quality education, not just buying change, but making informed decisions about an education with a unique mindset, one that is technological in nature. Let your school leaders know of your interest in having a strong technology and engineering curriculum. Help guide them toward knowing more about such programs.

Governmental Agencies

Sustained support for technology and engineering has come from state and national agencies such as the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA). There still remains, however, a need for departments of education at both the state and national levels to become more involved and gain a deeper understanding of this type of education.

If STEM education is to be notably effective, it has to become more than the science and mathematics education of the past. Agency personnel must understand that technology provides much more than the delivery of instruction and that it has a content base of its own—focusing on technological literacy. To date, there has been little evidence of understanding by departments of education of how technology and engineering are different and yet crucial in strengthening science and mathematics education. More of the same education as in the past is not the answer. Supporting an education that promotes knowledge and understandings about technological literacy is the answer to having a stronger STEM program. All concerned citizens should assist these agencies in fully understanding technology and engineering programs. Until they do, little progress

Technology and engineering have proven to be critical components in solving societal problems. Alone, science and mathematics fall short of allowing students to truly implement the knowledge necessary to make a better society.

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will be made towards funding that will truly make technology and engineering equal STEM subjects.

Legislative Bodies

While legislators do not determine curriculum content for the public school, they can express to school leaders their interest in having stronger technology and engineering programs as a part of a STEM education. Few elected officials have an adequate background that would allow them to fully understand the issues related to a strong program. They must be made aware of the many opportunities to provide a technological education—and that teaching the "S" and "M" of STEM alone shortchanges students of the full benefits of a STEM education.

At the same time, legislators should be encouraged to advance STEM legislation in such a way that STEM subjects thrive in our schools—including legislation promoting more technology and engineering teachers, greater professional development, and an emphasis on ending technology and engineering teacher shortages. The shortage of qualified STEM teachers will make the job of education in creating a 21st Century Workforce more difficult. As a country, we need to act now to make our educational system STEM strong. As community leaders, we must make our concerns known.

Corporate Leaders

Corporate leaders can play many key roles in promoting technology and engineering education. They can become major advocates for the type of thinking that supports inventive thinking—learning to use design as a process in creating, and expressing the need for an education to prepare a technological worker. Their influence in both state and national legislation can bring attention to the need for informed workers with a background appropriate for tomorrow's technological world. Educators should be working with corporate leaders to utilize their resources with boards of education and on advisory groups. At the same time, corporate leaders should take advantage of every opportunity to advocate for the type of worker needed in their industries. These back-and-forth relationships provide student educational opportunities, prepared corporate employees, and an informed citizenry that can make better-informed decisions about technological issues that face our society.

Summary

The teachers who have provided the preceding program descriptions do not know all of the challenges that lie ahead for themselves or their students. Their current programs are in transition towards ideals that they are pursuing with an emphasis on technology and engineering within STEM. Even with this emphasis, science and mathematics are a key part of their teaching. These are veteran teachers who have had their share of failures and successes in both the classroom and the laboratories that they manage. They continue to explore new ideas and various areas of research and developed materials to become outstanding educators in tune with the leadership of the profession.

There are many teachers throughout the United States and in other countries who are experiencing the same type of excitement that captures one's ability to design, create, and innovate. These programs have many different titles that include technology, innovation, design, and engineering in one form or another. Therefore, we are seeing the spawning of an important subject area that can do much to prepare next-generation workers capable of using their talents in many ways to advance our fast moving, highly technological society.

The mission of such programs must be to increase understanding of technological literacy and design among all people. A strong STEM program is a curriculum thrust that works toward the mission by presenting the insight, providing the drive and communication, and questioning the efficiency of methods and approaches while delivering material of significance to people who will be experiencing sophisticated technology for the rest of their lives.

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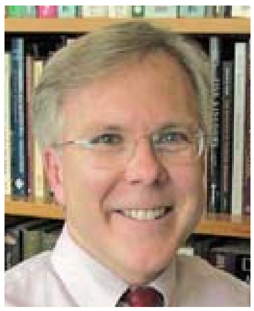

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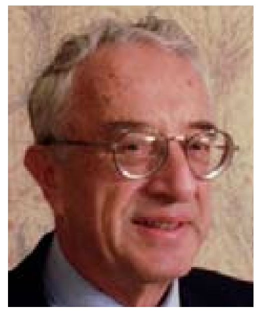

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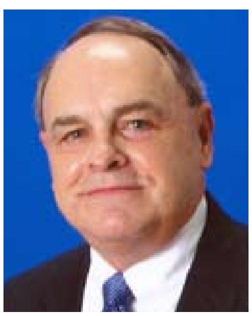

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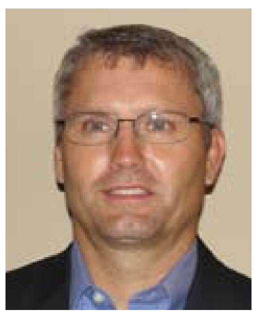

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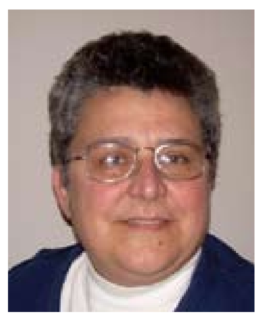

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We wish to recognize the work of Katie de la Paz and Kathie Cluff, whose editorial contributions have made this publication a reality. We thank all of the authors for their time, professional commitment, and dedication to science, technology, engineering, and mathematics. We would also like to acknowledge the ITEA Board of Directors for their desire and encouragement in making such a publication possible to further the work of the profession.

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