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TEACHER

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Materials appearing in the journal, including advertising, are expressions of the authors and do not necessarily reflect the official policy or the opinion of the association, its officers, or the ITEEA Headquarters staff.

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Building Technology and Engineering STEM Partnerships
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ITEEA BOARD OF DIRECTORS ELECTION RESULTS

ITEEA’s professional and life members have completed a balloting process to elect a new President-Elect and Directors for Regions I and III. Joining the ITEEA Board of Directors in March in Milwaukee are:

President-Elect: Jared P. Bitting, DTE
Jared is a Technology and Engineering Education Teacher and Department Chair at Fleetwood Middle School in Fleetwood, PA.

Region I Director: Philip A. Reed
Philip is Associate Professor at Old Dominion University in the Department of STEM Education and Professional Studies in Norfolk, VA.

Region III Director: Michael A. Sandell
Michael is a Technology and Engineering Educator at Chisago Lakes High School in Lindstrom, MN.

Also joining the ITEEA Board of Directors in March are:

R. J. Dake. R. J. is Technology Education Program Consultant in the Kansas Department of Education. He will represent the Council for Supervision and Leadership.

Geoff Wright. Geoff is an Associate Professor of Technology and Engineering Education at Brigham Young University, and he will represent the Technology and Engineering Education Collegiate Association.

Sincere thanks are extended to the new board members for taking on this leadership role, and to the other candidates for bringing such a wealth of experience and talent to the balloting process. By being part of the ballot, each of the candidates has demonstrated leadership in the field.

ITEEA WELCOMES EVERY SCHOOL IN ALBEMARLE COUNTY, VA!

Albemarle County, VA has taken the forward-thinking step of signing up every one of its schools (16 elementary schools, 5 middle schools, and 4 high schools) for an ITEEA Group Integrative STEM Membership. This countywide implementation provides each school access to the latest in technology and engineering education and STEM with ITEEA journals and publications, a teacher-to-teacher listserv, professional development, teacher and program awards, and discounts on curriculum, conferences, and even professional liability insurance. Interested in how your school or district can participate in this Integrative STEM Membership program? Contact mwiley@iteea.org.

REDESIGNED WEBSITE

ITEEA member and former Children’s Council President Bob Claymier announces the remodeling of his elementary STEM webpage (www.stemiselementary.com/). Visitors will find a fresh new look, as well as have access to free standards-based elementary STEM activities, an opportunity to sign up for Bob’s free monthly STEM is Elementary newsletter, and information about an online elementary STEM course that is now available.

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**STEM Thinking!**

**INTRODUCTION**

Science, Technology, Engineering, and Mathematics (STEM) is a term seen almost daily in the news. It is a term with many meanings, but it is often directed at those involved in education and focuses on improving how STEM education is developed and delivered so that the U.S. can build a globally competitive workforce. For example, the recently released *Next Generation Science Standards* (NGSS, 2013a) discuss the need for new science standards by noting a reduction of the U.S.’s competitive economic edge, lagging achievement of U.S. students, the need to prepare for STEM careers needed in the modern workforce, and the need for an educated society that is literate in science and technology.

STEM is involved in almost everything we do. In 2009, President Obama launched the Educate to Innovate initiative to move American students from the middle to the top of the pack in science and math achievement over the next decade (The White House, n.d.). Learning about the attributes of STEM and how they are connected can help promote innovation (Holt, Colburn, & Leverty, n.d.).

Teachers involved in STEM education must take the challenge of learning more about the STEM areas and begin showing students how they are connected. To begin this transformation, teachers must become STEM Thinkers who can show their students how STEM is involved in most of the products and systems they use in their daily lives. STEM Thinking can be defined as “purposely thinking about how STEM concepts, principles, and practices are connected to most of the products and systems we use in our daily lives.”

At the collegiate level, STEM education encourages students to pursue STEM careers in order to meet the growing need for trained professionals in these areas. The focus of this article is on teachers at the primary and secondary levels (i.e., P-12) who are involved in teaching about one or more of the STEM areas in their classrooms. These teachers, who come from a variety of STEM education areas, are typically involved in using hands-on and inquiry-based learning strategies that challenge students to solve real-world problems and explore their curiosities of the natural and human-made worlds. Today in our schools, teaching about STEM can take place in many general education and career and technical education subject areas.

One of the things that I’ve been focused on as President is how we create an all-hands-on-deck approach to science, technology, engineering, and math… We need to make this a priority to train an army of new teachers in these subject areas, and to make sure that all of us as a country are lifting up these subjects for the respect that they deserve.”

President Barack Obama

Third Annual White House Science Fair, April 2013
such as agriculture, science, health, technology and engineering, and family and consumer science.

**WHY BECOME A STEM THINKER?**

Teachers who become STEM Thinkers can actively promote the concept of STEM Thinking to their students who will begin to learn and appreciate the interconnectedness of STEM and how it impacts their lives. Students who become STEM Thinkers may be able to gain a better understanding of the concepts, principles, and practices of STEM as they begin to see the “big picture” of STEM, and may develop an interest in pursuing a STEM career.

There are many concepts, principles, and practices taught in STEM, and often these ideas “crosscut” among the STEM disciplines. For example, “pressure” is equally important in science and engineering in developing new technology (e.g., a lightweight airplane) and can mathematically be determined. The following are examples of popular concepts, principles, and practices associated in the STEM areas:

**Science**
- Experimentation and The Scientific Method
- Natural World
- Energy and Matter
- Force and Pressure
- Hydraulics and Pneumatics

**Technology**
- Developed by Science and Engineering
- Human-Made World
- Positive and Negative Impacts
- Extending Human Potential
- Tools and Materials
- Computers

**Engineering**
- Engineering Design
- Creating Technology
- Inventions and Innovations
- Applying Math and Science
- Systems and Systems Thinking
- Materials and Properties

**Mathematics**
- Numbers and Operations
- Formulas
- Patterns and Relations
- Measurement
- Geometry
- Drafting (2D and 3D)

STEM Thinking can promote learning about how STEM is connected to familiar technologies, such as the jet airplane.

STEM Thinking can lead teachers to become STEM integrators who can teach students how to apply STEM subject matter in a variety of “real-world” inquiry-based learning activities. For example, a teacher practicing STEM integration may develop a lesson on greenhouses and have students use the “scientific method” to measure temperatures during different environmental conditions, and then challenge students to use the “engineering design” process to build a greenhouse that keeps the temperature in a specified range.

STEM integration is a curricular approach that combines the concepts of STEM in an interdisciplinary teaching approach (Wang, Moore, Roehrig & Park, 2011). Satchwell and Loepp (2002) describe an integrated curriculum as “one with an explicit assimilation of concepts from more than one discipline.” In a STEM-integrated setting, Laboy-Rush (n.d.) notes that, “Integrated STEM education programs apply equal attention to the standards and objectives of two or more of the STEM fields” (p. 3).

In trying to define STEM integration, most argue a need for making connections across the STEM disciplines, but no one clear definition exists. Sanders’ (2009) views on integrative STEM education involve purposely creating connections between science and technology and promoting an idea of “purposeful design and inquiry” that combines technological design with scientific inquiry. The authors of the recent report, *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*, were unable to achieve consensus on a concise and useful definition of integrated STEM education and note “there is little research on how best to do so or on whether more explicit
connections or integration across the disciplines significantly improves student learning, retention, achievement, or other valued outcomes” (NAE & NRC, 2014, p. 23).

STEM Thinking also helps to promote STEM literacy. A basic definition of STEM literacy is being able to “know, understand, use, and evaluate the STEM concepts, principles, practices, artifacts, and phenomena being studied.” Knowing involves being able to identify the idea or topic being studied. Understanding involves describing how it works or operates and being able to transfer this understanding to various situations. Using deals with being able to operate it. Evaluation deals with assessing the item or topic being studied and making a judgment as to its impacts, which may be positive or negative in nature. For example, a STEM-literate person would be able to identify a technological artifact such as a tablet computer, describe how it works, use it, and discuss its impacts on society.

STEM literacy combines the literacy requirements of each of the STEM areas. Developers of STEM standards provide concise definitions of literacy in their related area of study. For example, in technology and engineering education, technological literacy has been described as “one’s ability to use, manage, evaluate, and understand technology” (ITEEA, 2000/2002/2007).

You for Youth, sponsored by The U.S. Department of Education, promotes learning in after-school hours and has developed 21st Century Community Learning Centers to promote learning in a variety of subject areas, including STEM. You for Youth (n.d.) provides a good definition of STEM literacy, noting that it “relates to a student’s ability to understand and apply concepts from science, technology, engineering, and mathematics in order to solve complex problems” and providing good basic literacy definitions for each of the STEM areas as shown below.

- Scientific literacy is the ability to use knowledge in the sciences to understand the natural world.
- Technological literacy is the ability to use new technologies to express ideas, understand how technologies are developed, and analyze how they affect us.
- Engineering literacy is the ability to put scientific and mathematical principles to practical use.
- Mathematical literacy is the ability to analyze and communicate ideas effectively by posing, formulating, solving, and interpreting solutions to mathematical problems.

STEM Thinking also promotes systems thinking. Systems thinking involves considering all the parts of a system that make up a whole (e.g., a home’s air conditioning system is made up of many parts including a thermostat, compressor, and blower). When learning about systems, students learn concepts related to the purpose of the system, subsystem interactions, and system processes that include inputs, outputs, feedback, and control (NAGB, n.d.). Learning about systems thinking is important and will be a major area addressed in the first-ever national assessment in Technology and Engineering Literacy. In 2014, the National Assessment of Educational Progress (NAEP), commonly called the Nation’s Report Card, will begin assessing, at the eighth grade, students’ literacy in the major areas of (1) Technology and Society, (2) Design and Systems, and (3) Information and Communication Technology (NAGB, n.d).

**STEM EDUCATION**

To become a STEM Thinker, it is helpful to have a little background on the term STEM and a good understanding of the meaning of STEM education. In his discussion on *Advancing Stem Education: A 2020 Vision*, Bybee (2010) provides an excellent discussion on the use of the term STEM. He notes the term “had its origins in the 1990s at the National Science Foundation (NSF) and has been used as a generic label for any event, policy, program (e.g., STEM Academy), or practice that involves one or several of the STEM disciplines.” He also observes that it is a “slogan that the education community has embraced without really taking the time to clarify what the term might mean when applied beyond a general label, and in the U.S. the term is often interpreted to mean science or math, and seldom does it refer to technology or engineering” (p. 30).

There are many definitions and interpretations of STEM education and no clear consensus on its meaning. For example, STEM education could refer to a stand-alone STEM course (e.g., physics or calculus) or a program of study that includes a
variety of courses from the STEM areas. Although there is no clear consensus on the meaning of STEM education, the term is often used in a context that emphasizes an immediate need to improve education in STEM. Tsupros, Kohler, and Hallinen (2009) provide an often quoted definition of STEM education: “an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise, enabling the development of STEM literacy and with it the ability to compete in the new economy.”

Today, improving STEM education is promoted by all professional organizations involved in STEM education (e.g., National Science Teachers Association) in addition to other national organizations that promote STEM education (e.g., the STEM Education Caucus, the STEM Education Coalition, and the Triangle Coalition for STEM Education). For example, the STEM Education Caucus seeks to strengthen STEM education at all levels (K-12, higher education, and workforce) by providing a forum for Congress and the science, education, and business communities to discuss challenges, problems, and solutions related to STEM education. The STEM Education Caucus notes that there is a pressing need for STEM education in the U.S. because “today, an understanding of scientific and mathematical principles, a working knowledge of computer hardware and software, and the problem-solving skills developed by courses in STEM are necessary for most jobs.” The Caucus further states that STEM education is responsible for providing our country with three kinds of intellectual capital: (1) scientists and engineers who will continue the research and development that is central to the economic growth of our country, (2) technologically proficient workers who are capable of dealing with the demands of a science-based, high-technology workforce, and (3) scientifically literate voters and citizens who make intelligent decisions about public policy and who understand the world around them (STEM Education Caucus, n.d.)

STEM education should promote STEM integration that shows how the components are connected. In the U.S., almost all K-12 schools require the core STEM subject areas of math and science and offer a variety of courses in these areas. Technology and engineering education is offered in varying degrees around the nation, with most courses in these areas being offered as electives. However, at the 6-12 grade levels, STEM courses are typically taught in “silos” by teachers who often have discipline-specific training, but limited opportunities to learn how the STEM areas are integrated together. In the elementary grades, if STEM is taught, it will typically be taught by a classroom teacher who works in a predominately self-contained classroom. In the future, STEM education may consist of stand-alone STEM courses taught by “STEM teachers” who have received in-depth training in all the STEM areas. Also in the near future, STEM education may broaden to include additional subject areas. For example, there is a movement in the U.S. by some to add art (“STEAM”) to show how art and design help bring creativity and innovation to STEM (STEM to STEAM, 2013).

National curricula that promotes STEM integration at both the primary and secondary levels continues to be developed by various organizations as STEM education becomes a priority across the nation. At the national level, examples of organizations aggressively developing integrated STEM curricula include Project Lead the Way (PTLW), the International Technology and Engineering Educators Association’s Engineering by Design™ (EbD™) curricula, and the Engineering the Future and Engineering is Elementary curricula projects, developed by the Boston Museum of Science.

At the university level, STEM education encourages students to pursue STEM careers in such areas as engineering, computer science, science, agriculture, and mathematics. Careers in these areas are in high demand, and workers are needed to help keep the U.S. competitive with the rest of the world. For example, the most recent Bureau of Labor Statistics (BLS) occupational projections for the period 2008–18 suggest that total employment in occupations that NSF classifies as science and engineering will increase at more than double the overall growth rate for all occupations (NSF, 2012).
Technology (IPST) sponsored an all-day roundtable meeting in 2013, Thailand’s Institute for Promoting Science Teaching and to interact with other STE subjects. STE often challenges to “silos,” with little interaction occurring between subject teachers. STE will encourage STE teachers to interact with other STE teachers.

STEM education and building a STEM-educated workforce is important to the U.S. as well as many other nations around the world that understand that STEM professionals working together will be needed to solve many of the global issues and problems the world faces today (e.g., global warming, air and water pollution, clean drinking water, and food security). Today, in many areas of the world, improving STEM education has become a priority. For example, in Europe, “inGenious” is the European coordinating body in STEM Education with a goal to reinforce young Europeans’ interest in science education and careers and thus address anticipated future skills gaps within the European Union (inGenious, n.d.). In Asia, the Association of Southeast Asian Nations (ASEAN) economic community (AEC) is working toward transforming ASEAN into a single market and production base by 2015. Important to this transformation is improving STEM education in the region. For example, in January 2013, Thailand’s Institute for Promoting Science Teaching and Technology (IPST) sponsored an all-day roundtable meeting to address the need to develop a STEM workforce in ASEAN countries through world-class quality STEM education (IPST, 2013).

BECOMING A STEM-THINKING TEACHER

Becoming a STEM-Thinking teacher is not difficult; however, it will challenge many teachers to step outside their “subject comfort zones.” In the U.S., the primary STEM subjects are often taught in “silos,” with little interaction occurring between subject teachers. STEM Thinking will encourage STEM teachers to interact with other STEM teachers.

Those involved in teaching in STEM areas who wish to become STEM Thinking teachers must first begin by accepting the challenge to want to learn more about how STEM concepts, principles, and practices are connected to most of the products and systems we use in our daily lives. At a minimum, STEM Thinking teachers will need to learn to accurately define and describe the components of STEM, be able to implement inquiry-based learning into their programs, and be able to show STEM Thinking in action.

Advanced STEM Thinking teachers will know how to develop and deliver integrated STEM curricula. In order to do that, teachers will be need to have a very good understanding of the standards covered in each of the STEM areas and know how to develop standards-based curricula. They will need to learn about the various instructional strategies, teaching methods, and assessment techniques that are commonly used in the STEM areas. They should also have a very good understanding about career options available in STEM and its related areas.

THE COMPONENTS OF STEM

STEM Thinkers need to develop a good awareness of each of the components of STEM. A STEM Thinking teacher must be able to able to clearly and quickly define the STEM components. A basic definition of each of the STEM areas is as follows:

- **Science**: study of the natural world.
- **Technology**: modifying the natural world to meet the needs and wants of society.
- **Engineering**: using math and science to create technology.
- **Mathematics**: a language of numbers, patterns, and relationships that tie science, technology, and engineering together.

To gain in-depth knowledge of each of the STEM areas, teachers are encouraged to review the national standards associated with each of the disciplines. All of the STEM areas except engineering have national content standards that are used to identify what is important to teach in that area. Standards identify the content that students should know and be able to do in order to become literate in a particular area of study.

National standards in math (*Principles and Standards for School Mathematics*) are available from the National Council of Teachers of Mathematics (NCTM). In addition, to try to build consistency and quality in the teaching of math and other subjects in the U.S., the Common Core State Standards Initiative (CCSS) has been adopted by 45 states and provides a detailed set of grade-by-grade standards that can be immediately adopted as a state standard by-grade standards that can be immediately adopted as a state standard by-grade standards that can be immediately adopted as a state standard by-grade standards that can be immediately adopted as a state.
curriculum document (AMTE, n.d.). In technology and engineering education, content standards (Standards for Technological Literacy: Content for the Study of Technology) are available from the International Technology and Engineering Educators Association (ITEEA). The recently released standards in science education (Next Generation Science Standards) are available from the National Science Teachers Association (NSTA).

**INQUIRY-BASED LEARNING**

STEM Thinking teachers use inquiry-based learning strategies and know the popular approaches used in the teaching of science, technology, and engineering. Inquiry-based learning describes approaches to learning that are based on the idea that when students are presented with a scenario or problem and assisted by an instructor, they will identify and research issues and questions to develop their knowledge or solutions (Inquiry-based Learning, n.d.).

Science education uses a form of inquiry-based learning known as “scientific inquiry.” In technology and engineering education, a popular approach to solving problems is known as “engineering design.” Both approaches are similar in nature, with the major differences being how the problems or questions are asked and solved, remembering that science explores the natural world and that technology and engineering focus on the human-made world. Next Generation Science Standards (2013c) notes that “scientific inquiry involves the formulation of a question that can be answered through investigation, while engineering design involves the formulation of a problem that can be solved through design.”

Presented in A Framework for K–12 Science Education (NRC, 2012) are the multiple ways in which scientists explore and understand the world and the multiple ways in which engineers solve problems. A STEM Thinking teacher would be able to describe the practices used by scientists and engineers to explore the world and solve problems as follows:

- Asking questions (science) and defining problems (engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics, information and computer technology, and computational thinking
- Constructing explanations (science) and designing solutions (engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

In the building of this boat, how important is it that the student knows about concepts, principles, and practices of STEM?

In the teaching of STEM, students can learn to apply inquiry-based learning approaches through a variety of instructional methods. One very popular approach that STEM Thinking teachers would use is Problem-Based Learning (PBL). PBL promotes developing critical thinking and problem-solving skills as students are challenged with real-world problems to solve, and it can be used to investigate scientific or technological problems.

To investigate a scientific problem or question (e.g., What type of insulation container will keep ice from melting for the longest time?), the scientific method can be used. The scientific method is a very controlled approach to investigating problems and typically requires following a set of prescribed steps that include stating a hypothesis, conducting an experiment, analyzing the data, and reporting the findings.

To investigate a technological or engineering-related problem (e.g., a need exists to build a small ice container that can be used to transport medicine that needs to be refrigerated), the engineering design approach can be used. In technology and engineering education, students are often presented with an engineering or technological problem to solve as an engineering design challenge that presents the context of the problem, the problem, and the criteria and constraints that must be adhered to when solving the problem. Engineers face many challenges and problems that must be solved when developing a new technology. To help them solve these problems, engineers apply mathematical and scientific principles (e.g., calculus and physics).
The engineering design process is fundamental to technology and engineering and is a problem-solving approach that is presented in many similar variations. In ITEA’s Standards for Technological Literacy (STL) (ITEA/ITEEA, 2000/2002/2007), many of the standards are focused on learning about design, how to do design, and learning about the designed world (e.g., construction and manufacturing). STL describes an “engineering design” process that engineers use when developing a new technology that includes:

- Defining a problem
- Brainstorming
- Researching and generating ideas
- Identifying criteria and specifying constraints
- Exploring possibilities
- Selecting an approach
- Developing a design proposal
- Making a model or prototype
- Testing and evaluating the design using specifications
- Refining the design
- Creating or making it
- Communicating processes and results

Both the scientific method and engineering design promote active, hands-on, experiential student-centered learning that requires students to apply what they are learning in the classroom. Hands-on learning using real-world problems motivates students to learn the materials and helps to develop an understanding of the content being learned. It should be noted that NGSS (2013b) “represent a commitment to integrate engineering design into the structure of science education by raising engineering design to the same level as scientific inquiry when teaching science disciplines at all levels, from kindergarten to Grade 12” (p. 10).

When using inquiry-based learning in the classroom, STEM Thinking teachers must continually remember to assess students using both formative and summative assessment methods that can be used by teachers to adjust student learning. For example, formative assessment methods such as asking students to reflect on how they are doing or reviewing their lab notebooks can help teachers to understand the approaches students are using to solve the problem. Summative assessment would involve tests of the materials presented or evaluation of the completed models or prototypes built to address the problem.

**STEM THINKING IN ACTION**

In the classroom, STEM Thinking teachers can put STEM Thinking into action, beginning with a lesson objective of purposely showing students how STEM concepts, principles, and practices are connected to most of the products and systems they use in their daily lives. In this STEM Thinking example, the object to be examined is a glass Coca-Cola bottle.

Although the U.S. uses mostly plastic bottles for soft drinks, many places in the world use glass bottles that can be recycled and refilled to help keep the cost of soda down. Another purpose of using the glass bottle is to help students become global thinkers. Too often students become U.S.-centric in their thinking, and providing them with global perspectives in the classroom can help them to realize and understand that the world is connected and comprised of a variety of cultures, norms, and practices that may be different from their own.

The lesson would begin by showing students a Coca-Cola bottle and having a discussion that addresses questions such as where it came from, why glass is being used, whether they think it may taste different, and why the U.S. uses mostly plastic or aluminum for soda and other beverages. Note: many large supermarket stores in the U.S. sell glass soft drink bottles that have been imported from Mexico.

After the discussion on use of the glass bottle, the teacher would present a discussion on how the object is connected to each of the STEM areas and encourage students to become STEM Thinkers and identify other STEM connections. Shown on page 15 are some STEM connection examples for the Coca-Cola glass bottle.
Science Connections
- Scientists used “natural ingredients” to develop the formula for the soda drink.
- Science was needed to develop glass that is made using natural ingredients such as sand.

Technology Connections
- The glass bottle was invented long ago. It is an example of a technology that was developed to hold liquids.
- An innovation of the glass bottle is the plastic bottle.
- Manufacturing technology is used to make the bottles.
- Transportation technology is used to deliver the bottle to the store.

Engineering Connections
- Engineers used engineering principles and practices to develop the technology needed to mix and fill the glass bottles with soda.
- Engineers and scientists worked together to develop methods to clean and sanitize the bottles so that they could be safely reused.

Mathematics Connections
- Proper measurements were needed in the development and design of the glass bottle.
- Math is used to measure the amount of liquid in the bottle.

At the end of the STEM Thinking lesson, students could be given an “engineering design challenge” that requires the use of engineering design to solve an identified problem. Examples of engineering design challenges for the Coca-Cola bottle might be to develop a holder for it so it does not tip over when bumped, a way to protect it, a way to automatically dispense a prescribed amount of soda, or a way for a disabled person to open it with one arm. In addition, students could learn to use the scientific method by setting up a taste test (e.g., between different brands of cola, or the same type of cola, but from a different country).

CONCLUSION
Teachers involved in teaching some aspect of STEM in their classrooms or programs are encouraged to become STEM Thinkers. STEM Thinking is a skill that promotes purposely thinking about how STEM concepts, principles, and practices are connected to most of the products and systems we use in our daily lives. Teachers who become STEM Thinkers are then able to transfer this skill to their classrooms where they teach their students to become STEM Thinkers, helping them gain a better understanding of the materials being covered and preparing them for life and careers in the 21st century that are heavily influenced by science, technology, engineering, and mathematics.

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This is a refereed article.
INTRODUCTION

Technology education has long been recommended as a viable vehicle for integrating multiple subject areas (Bonser & Mossman, 1923; Maley, 1984, 1988). Dating back to manual arts, Charles Bennett (1917) believed the field should “serve as a method or means of teaching other subjects” (p. 27). Through the example of a graphic arts project, Bennett discussed the integration of reading, history, and math that naturally overlap as students designed a picture book. Extending this belief, Donald Maley stated that industrial arts curricula should also “include strong linkages with communications, anthropology, psychology, history, and economics” (Maley, 1988, p.1). More recently, the purview of Integrative STEM Education (I-STEM ED) is “technological/engineering design based pedagogical approaches to intentionally teach content” (Wells & Ernst, 2012, para. 1). As Wells and Ernst (2012) suggest, “Integrative STEM Education is equally applicable at the natural intersections of learning within the continuum of content areas, educational environments, and academic levels” (para. 2). Although Wells and Ernst address math and science integration, they further posit that any subject is an equally viable option for integration through technological/engineering design. Clearly, a foundational belief for technology education has been, and is, integration of multiple educational disciplines. However, within technology education and alongside current STEM education reform, there has been a skewed focus on mathematics and science integration.

In the last year alone, more articles printed in the Technology and Engineering Teacher (TET) journal have focused on the integration of mathematics and science than any other discipline. Although many authors alluded to connections outside of STEM, the focus was on school subjects directly related to STEM education. This can be seen from applying mathematics concepts to solve a robotics challenge (Grubbs, 2013) or bat design (Cantu, 2012), to including science concepts for the creation of a windmill (Love & Strimel, 2012). Considering the concerns over reported low U.S. mathematics and science scores compared to other countries (Provasnik et al., 2012), there is no doubt that technology and engineering education should intentionally incorporate STEM concepts as often as possible. However, as current STEM educational reform has directed efforts toward science and math integration, the effect is leading to the deconstruction of existing silos between STEM subjects and creation of ones exclusive of other subject areas.

STEM INTEGRATION

Current STEM Education reform can be seen through two lenses. First, from a national security and economic concern perspective (NSB, 2007), there is a need for more STEM graduates and increased student test scores in mathematics and science. Secondly, STEM Education represents a developing need for authentic, integrative experiences for students. Although there is an increasing focus on the four disciplines most commonly cited in the STEM acronym, there remains an ad-
ditional need for students to see all subjects in their most natural settings. Thus, subjects such as reading, writing, geography, and history all have equal importance and capability of being integrated into K-12 technology and engineering education. The I-STEM ED graduate program at Virginia Tech has already conceptualized such a pedagogical approach that extends beyond the STEM education disciplines and welcomes integration of multiple school subjects.

There is also a need for technology education to educate a “citizenry capable of solving issues related to technological developments such as pollution, housing, transportation, and so on” (Maley, 1970, p. 43). Through technological/engineering design challenges, students are situated within an environment that requires application of knowledge and concepts from multiple subject areas even beyond STEM disciplines to solve pressing technological issues. Technological developments related to manufacturing and housing provide an ideal context not only for Technology Education, but open the door for World Geography. Concepts that can be intentionally incorporated into design challenges and are essential in solving global technological issues include culture, climate, interpreting maps, and understanding the geographical resources of a region. This article discusses the status of World Geography Education and the importance of these concepts in developing 21st century students. Moreover, the authors will also showcase how World Geography concepts can be intentionally taught through a technological/engineering, design-based learning challenge that requires students to solve a global housing issue.

**GEOGRAPHY EDUCATION BACKDROP**

Just as each STEM discipline has reported lackluster instruction and low student test scores, Geography Education has reported equally unfavorable results throughout the nation. Specifically, the 2010 National Assessment of Educational Progress (NAEP) “found that fewer than 30% of American students were proficient in geography” and “more than 70% of students at fourth, eighth, and twelfth grades were unable to perform at the level that is expected for their grade” (Edelson & Pitts, 2013, p.1). Moreover, considering the belief that students will be expected to make decisions that affect the environment such as “which products to buy and how to dispose of them” (Edelson & Pitts, 2013, p. 2), this data is further alarming and even more reason to integrate geography concepts in technology education.
Although environmental decisions might seem insignificant to students, they have far-reaching consequences globally. Manufacturing, for example, can illustrate how the production of goods and by-product pollution of one nation can affect another. Through the incorporation of World Geography, students would analyze and evaluate the effects these technologies have on environments outside of one’s own. Secondly, students’ ability to have an understanding of the effects of technology is in direct alignment with Standards 4, 5, and 6 from Standards for Technological Literacy (ITEA/ITEEA, 2000/2002/2007).

Furthermore, the recent release of Next Generation Science Standards (NGSS) with the infusion of engineering design, lends itself as well, through crosscutting concepts. One such example is Standard MS-ETS1-1, which states that students can “Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions” (NGSS Lead States, 2013, para 1).

Global housing needs can provide another context and overlap for World Geography and Technology Education. This interaction is an ideal opportunity to develop students’ understanding of differences in culture, climate, ethnic background, and population increases as they design products and services based on varying world populations. One such example has been construction of modular homes for other countries or global markets. This process is not only more cost-effective, energy-efficient, and maximizes space (International Modular, 2013), but also has proven recession-resistant as the recent U.S. housing industry has forced companies to look elsewhere for business. Companies are able to design, build, ship, and construct modular homes for countries across the globe. This is not without proper research and understanding of the cultures, economies, climate, and wants and needs of that community and provides a great context for students to apply and discover engineering and geography principles. Therefore, students were asked to take on the role of a modular construction company that would intentionally position it in a context requiring application of technology, engineering, and world geography concepts.

LESSON CONCEPTION AND DESIGN CHALLENGE

Through an I-STEM Education approach, a World Geography and Technology and Engineering teacher collaborated to align their units through overlapping concepts that appeared at “natural intersections” of the learning process. The desire for collaboration was spurred by interest of both authors to provide authentic, integrative learning experiences for their students. Next, concepts and standards from World Geography and Technology Education were discussed prior to the choosing of an activity. This grounded future planning and ensured that a subsequent design challenge would intentionally provide students the opportunity to apply and discover concepts related to both disciplines. Lastly, following Wells and Ernst’s (2013) belief that “the goal of T/E design-based learning is distinct in that it seeks to promote integrative STEM thinking through the design of a product, system, or environment that provides solutions to practical problems” (para. 3), a common design challenge was agreed upon. Students were required to work through the technological/engineering design process to conceptualize and make a context-appropriate modular home for an underdeveloped country that was either chosen by them or suggested by the teacher. Many chose countries related to their heritage or travel interests. Most students have an intrinsic desire to solve ill-defined problems, and as they are working through design challenges, they are naturally searching for valuable and appli-
cable information when considering tradeoffs and constraints. It is, however, up to the teacher to create instruction that provides opportunities for students to discover or apply specific intended concepts across multiple subjects.

The design challenge, although centered on the design and prototype of a modular home that would be shipped from the U.S. to an underdeveloped country, began with the scenario in Figure 1. Furthermore, an advanced organizer was used to engage students at an abstract level to bridge prior and future learning. One example that was shared with students was how a lack of cultural understanding can lead to poor business decisions. This was explained through the use of the video game console, Xbox One. Robson (2013) found that when Xbox One is translated into Japanese, it is batsu-ichi or strike one. This slang term is used to describe someone who is divorced, and could affect purchases by consumers in that country. A discussion with students informed them that this decision might cost Microsoft millions of dollars in the video game industry, as Japan represents one of the largest video game markets, and that product decisions change depending on the culture being represented.

After students have been briefed on anticipated content to be covered, they’re divided into groups of four and given a specific responsibility for the duration of the project. The project calls for a civil engineer, geographic specialist, architect, and marketing liaison. Each role provides group members with a necessary component needed to complete the object at hand: a scale model of a modular house. Designating a specific role to each student gives the group a work-distribution component, one that removes the opportunity for the group to place the focus on one student, and instead makes the project collaborative, with each student playing an essential role in the design. At the completion of each day the students must complete a reflection detailing their decision-making process and how it impacts the group dynamic and modular house construction. This greatly helps the instructor to guide students to discovery of knowledge and assist them in making connections to the desired learning outcomes.

A performance-based rubric is also distributed to students ahead of time to ensure understanding of learning expectations. The rubric assessed students’ ability to work through the engineering design process by evaluating completed models and addressing students’ ability in explaining concepts during their final presentation. Also, students are required to create sketches, fully dimensioned blueprints, and a final scale model of their house design, illustrating the functionality of what they are creating (Figure 2). Along with the model, they will need to show how weather forces affect the house and how they plan to eliminate structural deficiencies with only the resources available on their island. This blueprint will then be examined by the zoning board of the island (the instructor) and deemed satisfactory or unsatisfactory. If satisfactory, students will move into the production phase of the project. Students will produce their projects before being tested against the heavy winds, rain, and flooding that commonly occur throughout their chosen or selected region. In Figure 3, students test preliminary structural components against live and dead loads. Students are also prompted by the teacher throughout the design challenge to consider who would reconstruct the structure and how this would affect blueprints, material availability in other countries, and differences in supply and demand of building materials in comparison to the U.S. Figure 4 illustrates opportunities for student analysis of specific structural components such as I-beams, columns, and C-channels. This extends beyond students’ unintentional construction with little application of authentic building components used by engineers, while aiding in development of students’ ability to identify material transfer properties (Grubbs, 2014) such as torsion, compression, and tension.
CONCLUSION

Current STEM Education reform has afforded technology education increased attention and opportunities to become integrated with other STEM subject areas. However, it has also further welcomed integration across multiple school disciplines not exclusive of STEM. Through design-based learning, which has been suggested to engage students in a creative problem-solving process focused on solving multidisciplinary-based problems (Davis, 1998), it is difficult to find challenges that do not encompass a plethora of domains. An analysis of the Grand Challenges for Engineering (Perry, et al., 2008) illustrates problems that are cross-disciplinary, containing concepts that reach across multiple subjects. From providing access to clean water to making solar energy economical, concepts from any school subject can easily be integrated into a technological/engineering design-based pedagogical approach. Furthermore, both teachers noted that students were far more engaged throughout the learning process in comparison to previous instructional strategies.

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water, conflict, and technology

INTRODUCTION
It is easy for people in developed countries to take water for granted, but the availability of water suitable for drinking, sanitation, agriculture, and manufacturing is a complicated global issue. In developed countries, most citizens have access to indoor plumbing that delivers potable water from ground wells or public delivery (e.g., municipal water systems). Most of these citizens also have access to sewer systems that use water to move waste. Millions of people in underdeveloped and developing countries do not have access to reliable sources of potable water and effective sewers. According to Tetra Tech (2014), an engineering consulting and construction company, 89 percent of rural Afghans defecate without sewers or latrines, and 75 percent drink from unclean sources. Regardless of whether or not a given country is developed, most countries around the world have a variety of concerns about water. Water resource issues are influenced by global poverty, global politics, global warming, and the global economy, but engineering and technology can be part of localized solutions.

WATERWORLD
In the movie Waterworld, humans who survive a world flood must then develop primitive means of surviving in a world that is almost 100 percent covered by saltwater. Their lives are disrupted in drastic ways by the effects of global warming. Luckily, in real life, only 70 percent of the world is covered by the oceans, but current estimates of glacial melting and oceanic thermal expansion predict a rise in ocean levels over the next 50 years that could displace millions of people (Michel, 2009). While this is nothing like the flood in Waterworld, a four-foot rise in ocean levels requires governments to start planning now for the relocation of some coastal communities and the location and construction of their water systems.

Weather plays a role in the sources of water on which people depend in their own localities. For example, in high elevations and in extreme northern and southern latitudes, people take drinking water from streams that are fed by glaciers and snowmelts. Glaciers and annual snowmelts were reliable sources for years, but now there is fear that these sources will disappear because of global warming. In lower elevations of developed countries, drinking water is taken from wells, rivers, and reservoirs, but now there is concern about whether or not these aquifers and reservoirs will be replenished enough to remain reliable sources. Sustained drought is becoming more frequent. In deserts, well water is critical for life and agriculture, but as farmers drill deeper wells to access desert aquifers, the aquifers continue to be depleted. If global warming is disrupting weather patterns, snowfalls, and rainfalls, then dependence on traditional water sources may become an obsolete way of life. In a global water crisis, people would have to relocate, with catastrophic drops in property values, and move to places where they would be generally unwelcome. Because water is necessary for the irrigation of crops, food could be limited,
there could be widespread crop failure, and many manufacturers that depend on water for industrial processes would go out of business, causing widespread unemployment (Michel, 2009).

Table 1 shows a sampling of countries from around the world, and ranks these countries by fresh water extraction on an annual per capita basis. This is another way of estimating water use. The U.S. is listed because it is a known world leader in agriculture, manufacturing, and consumption. Germany is listed because it is a highly developed industrial country that is known to be conscientious about its water consumption. Brazil, Russia, India, and China, the BRIC nations, are listed because of their growing roles in the global economy, and the remaining countries are listed because of their poverty, instability, or inefficiency.

The U.S., one of the most developed countries in the world, has the third largest amount of fresh water in the world, and it uses the most water per capita. New installations of residential plumbing require low-flow devices, so there is some water conservation underway. However, more than one-third of this water is used in agriculture. In 2005, 37 percent of water was extracted for irrigation, and of that, 58 percent was taken from surface water sources. Forty-two percent was taken from groundwater sources. The use of groundwater increased with increased acreage being farmed. In 1950, 77 percent of all irrigation water was taken from surface sources. Today, the U.S. is using about three times more groundwater for irrigation than it used in 1950. And this is down slightly from a peak in 1980 because of more efficient irrigation technology, among other reasons. Most of this groundwater is used in western states where the conditions are the driest. Industrial uses accounted for only four percent of total extractions in 2005. Domestic (residential/household) use is much less. As in irrigation, total water use has leveled off since 1980 (U.S. Geological Survey, 2014).

Germany, another highly developed country, is well known for its culture of water conservation. Over the past 23 years, Germany has decreased its daily per capita usage by almost 14 percent. Residential conservation is so effective, in fact, that utilities must add extra water to sewer systems to adequately flush waste. Waste from low-flow plumbing has been clogging systems and damaging piping and controls. Just as in the U.S., agriculture and industry account for the vast majority of German water usage (Gersmann, 2012).

Kazakhstan, a developing nation, has a very high annual extraction rate per capita. It is not a developed country like the U.S. It grows cotton and extracts minerals and natural gas. Its own Ministry of Agriculture reports that inefficiency in infrastructure and coordination is responsible for Kazakhstan’s high per capita use rate (Ryabtsev, 2010). Ethiopia and Somalia are among the 18 countries in the world with the lowest gross domestic product per capita (Central Intelligence Agency, 2014). Somalia and Ethiopia extract the least amount of water of any countries on the list in Table 1. Ethiopia is relatively stable politically compared to Somalia, but Ethiopia’s poverty prevents it from developing water infrastructure. Somalia is poor and is a base for terrorists (Bureau of Counterterrorism, 2012). The presence of these terrorists creates more political instability and poverty, thus stifling development. Ethiopia and Somalia are hot and arid, and the lack of irrigation for agriculture creates a higher incidence of famine.

WATER AND CONFLICT

Even in developed countries, drought revives water conflicts between governments. In the U.S., California uses water from states to its east, water that those states will consider more and more essential to their own interests. This conflict can be more acute when countries are underdeveloped or developing. For example, Saudi Arabia developed its agriculture by extracting its potable ground aquifer. That groundwater is now running out. It is not a renewable resource. As a result, Saudi Arabia is starting to try to buy rights to extract water from the Nubian Sandstone

<table>
<thead>
<tr>
<th>Country in Order of per Capita Extraction</th>
<th>Total Renewable Water Resources (cu km)</th>
<th>Freshwater Extraction (cu km/yr)</th>
<th>per Capita Extraction (cu m/yr; all uses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>3,069</td>
<td>478.4</td>
<td>1,583</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>107.5</td>
<td>21.14</td>
<td>1,304</td>
</tr>
<tr>
<td>Afghanistan</td>
<td>65.33</td>
<td>20.28</td>
<td>823.1</td>
</tr>
<tr>
<td>India</td>
<td>1,911</td>
<td>761</td>
<td>613</td>
</tr>
<tr>
<td>Russia</td>
<td>4,508</td>
<td>66.2</td>
<td>454.9</td>
</tr>
<tr>
<td>China</td>
<td>2,840</td>
<td>554.1</td>
<td>409.4</td>
</tr>
<tr>
<td>Germany</td>
<td>154</td>
<td>32.3</td>
<td>391.4</td>
</tr>
<tr>
<td>Somalia</td>
<td>14.7</td>
<td>3.3</td>
<td>377.6</td>
</tr>
<tr>
<td>Brazil</td>
<td>8,233</td>
<td>58.07</td>
<td>306</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>1,227</td>
<td>35.87</td>
<td>238.3</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>122</td>
<td>5.56</td>
<td>80.5</td>
</tr>
</tbody>
</table>

(Central Intelligence Agency, 2014)
Aquifer in Africa, underscoring the truly global nature of water (Patterson, 2009). In the politics of water, there are the “haves” and the “have-nots.” When attempting to work together to solve water resource issues, if one country is more powerful than another, it will tend to dominate agreements over water extraction. For example, in the Nile River basin, Egypt and Sudan have an agreement about water use, but there are other countries in that basin that have no say in the agreement. Bangladesh and India are in a similar situation. Even though the two countries have an agreement in place to share river water, India tends to use too much of the upstream water before it flows through Bangladesh, and China is using much of the source water before it flows through India (Patterson, 2009).

While these conflicts of interest appear to exist at a local or regional level, they extend around the world. Where one country is without water, it may become necessary for another country, not in the same region, to intervene should instability arise. Suddenly, water becomes a global issue. Would France come to the aid of, say, Algeria, if another regional power were to deny Algeria water resources? To what extent has the lack of water in Darfur contributed to the Sudanese civil war? When countries or “powers” fail to provide for their people, instability often follows. In Africa, drought is often followed by internal conflict or civil war. Over the past 100 years, very few people have actually died over conflicts directly related to water, but to what extent could this change as global warming changes the climate, droughts increase, and instability spreads (Michel, 2009)? No answers to these questions are certain, but analysts recommend that policies on water include surface water and groundwater simultaneously (Patterson, 2009), and they recommend that countries collaborate (Michel, 2009).

**WATER AND TECHNOLOGY**

Humans need no technology to drink water. If a clean, natural spring were located, its water can be consumed directly. Most wells have absolutely no purification technology attached. However, society employs technology to extract, treat, and move water efficiently to locations where it is needed. Governments play a role in supporting the use of technology in the control of water. Local ordinances require residential construction to use low-flow plumbing controls. Typically, these controls are required to protect the local water supply from stress. It is a misconception to believe saving water at home will save the world from water problems, but it is the right thing to do. It establishes a culture of conservation at the grassroots of society. When the municipal system’s capacity is adequate, everyone saves money. Agriculture and industry have a profit motive to save through efficiency. Agriculture, as the largest consumer of water, truly has a responsibility to the rest of society to be a good steward of this precious resource. But no technological solution to the global water problem works well without considering local needs and international political collaboration. Nevertheless, engineering can provide assistance.

**Site-Specific Precision Irrigation**

Groundwater aquifers are not necessarily renewable. Irrigation must be done as efficiently as possible. Howell, Evett, O’Shaughnessy, Colaizzi, and Gowda (2009) describe the precise ways that fields can be irrigated under the control of new technologies. At the basic level, a field can be irrigated in a straight-line motion (lateral move) or in a rotating motion (center pivot). In modern, commercial agriculture, the overhead sprinkler is a typical delivery technology. It has a huge manifold constructed from metal pipe with nozzles across its length. The entire structure is supported on wheels and is elevated above the crops. Over the span of an entire field, there will be variations in soil and crop conditions. Knowing when to irrigate is the most important part of the entire process. Knowing how to irrigate with precision is what optimizes the process. The soil in one part of a field could retain water better than the soil in another part of the field.

Satellite and airplane sensing data have not been particularly useful in precision irrigation because the information takes too long to reach the field and, once published, typically lacks the specificity needed to judge the state of any particular field. Automated weather stations appear to be some help in determining local conditions. What seems to work the best is the deployment...
of crop and soil sensors in key locations in the field. They automatically broadcast data that represents current soil conditions. At the same time, software maps out the zones of the field that need more water and the zones that need less or no water at all. A programmable logic controller is at the heart of the automated control of the system. Data can be transmitted by various telemetry processes. Solenoids are mounted along the manifold control sets of nozzles to meter the right amount of water for any particular section of the field. All the while, an electric motor (or hydraulics) is moving the entire structure forward across the field. Global positioning satellites are used by the system to maintain its bearings as the overhead sprinkler moves (Howell, et al, 2009). The results of this type of technology are visible in the satellite photograph in Figure 1, the circular-shaped field.

Desalination

Humans inhabit most of the world, and many live near oceans. At very low elevations near the coast, as groundwater is pumped out of the ground, oceanic saltwater can invade the aquifer (Noseraie, 2001). Very arid regions that also have access to the oceans or access to groundwater may need to use desalination, completely or in part, to supply drinking water and water for irrigation. As fresh groundwater is used up, neighboring saline groundwater will move in to occupy that space. The use of groundwater for irrigation can cause a buildup of salty minerals in the soil (U.S. Geological Survey, 2003). So, in some circumstances, it makes sense to desalinate, but the process is so expensive that it is prohibitive in poor countries.

Desalination can be accomplished through distillation, the heating and cooling of saltwater to extract fresh water, or by reverse osmosis, the “filtering” of saltwater to extract freshwater. The basic method used to distill saltwater is to use heat and vacuum to create steam out of saltwater. When water is under vacuum, it vaporizes faster. Just like ocean water evaporating, the vaporized water, which is lighter than the minerals, rises from a bath and flows into a condensing chamber. The condensing chamber collects the “fresher” water. This basic process can be improved by heating the fresh water again and condensing it again. The condensation process can be helped by adding chilled fresh water. Because some minerals will always cling to some water molecules, multiple-stage distillation helps to desalinate water better (McGivern, 2010). Energy is used in the pumping process, the pressurization process, the heating process, and the condensation process. However, several countries, such as Japan, Russia, and Saudi Arabia, are using cogeneration. Desalination is powered by extra energy from a local power plant, typically nuclear or oil-fired (World Nuclear Association, 2014).

Because desalination is energy-intensive, the process is relatively expensive. However, it costs less to desalinate saline groundwater than it does ocean water because groundwater is much less salty (U.S. Geological Survey, 2003). Reverse osmosis represents about 60 percent of the world’s desalination capacity (World Nuclear Association, 2014). In reverse osmosis, saltwater is forced, under pressure, through a semipermeable membrane. The membrane blocks the passage of minerals but allows the smaller molecules of water to pass. If the saltwater is heated enough, the force with which the water passes through the membrane is greater, and the desalination process provides more water. If saline groundwater were used, savings could be realized after recouping the costs of drilling the deep well that would be required. This process is a sort of hybrid of distillation and reverse osmosis, which Dentel and Bryan (2009) call “direct contact membrane distillation.” The use of solar energy may be feasible with this hybrid method because the use of deep groundwater requires less energy than in conventional desalination. The groundwater is less salty, and it is already heated from deep within the earth.

WATER AND APPROPRIATE TECHNOLOGY

Filtering drinking water is one of the most common objectives of appropriate technology applied worldwide. Schumacher’s work in the last century characterized appropriate technology as (a) simple, (b) small scale, (c) low cost, and (d) nonviolent. The U.S. Office of Technology Assessment... refined these... as (a) small scale, (b) energy efficient, (c) environmentally sound, (d) labor intensive, (e) controlled by...
the local community, and (f) sustained at the local level (as cited in Wicklein & Kachmar, 2001, p. 4-5).

Why build a hydroelectric dam when a simple well will solve the problem? In helping the underprivileged, there have been many failed applications of relatively advanced or large-scale technology in the past where these criteria were not met. Suppose that an engineer is tasked with assisting a very poor, untrained, very remote group of people irrigate their fields. Suppose the engineer sets up a diesel engine and a pump, and gets the fields irrigated. The local people would be very pleased. They no longer have to carry water for irrigation. Afterward, if the engine breaks down, there would be no one who knows how to fix it. If it runs out of fuel, there is none within a day’s drive. An animal-powered mechanism is more sustainable and appropriate.

Extraction

There are millions of people around the world who depend on hand-powered water extraction from wells. In some cases, such an approach might be the best solution to water extraction needs based on the appropriate technology criteria above. However, there are many people who also lack well-pumping technology simply because it is not feasible for the power company to extend electrical service to them. Beltrán-Morales, Cohen, Troyo-Díezuez, Polanco, and Unda (2007) make the argument that solar water pumping meets some appropriate technology criteria and is sustainable where there is adequate solar density and poverty is not relatively acute. They especially focus on ranchers in Baja California Sur, Mexico, of low incomes who need electric water pumping but who are now using human, animal, or fossil-fuel pumping. They maintain that solar water pumps require no fuel, are easy to maintain, have long service lives, and no health risks. However, there are two things that get in the way. One is the cost of the systems. The other is a lack of water storage. In their study, the primary reason for water extraction is to water livestock. However, for household water use, an affordable solar pumping system can move about 160 liters per hour, costs about $50, and for anyone with access already to a well, is easy to install. There is basically no maintenance. For the ranchers, the Mexican government is providing subsidies that can help with the purchase of the systems, and pits can be designed for the storage of water.

Filtration

A widespread drinking water filtration technology, truly an appropriate technology, is slow sand filtration. Slow sand filtration requires very few resources and is very effective. The Centers for Disease Control (2011) describe the slow sand technology very well. Place about five inches of clean gravel in the bottom of a large, watertight container, like a plastic garbage can or a poured concrete box. Add another similar layer of course sand, and then add fine sand. Pour in enough fine sand so that only about ten inches of space is left at the top of the container. Extend a small diameter pipe out of the bottom. Run the pipe upward to the height at which the water level is to be established, about two inches above the sand level. Add a spout that will allow exiting water to pour into a bucket. Inside the container, just above the established location of the water level, add a shield that will protect the surface of the sand from disturbance when adding water. Add a lid that will seal the container. To load the system, fill the container with water. Over time, a layer of biological material will form at the top of the sand. This layer filters out most contaminants and harmful bacteria but does not filter viruses well. The user should pre-filter solids from the source water before it is added to the system. As water is added at the top, filtered water pours out of the spout.

CLASSROOM STEM

Of course, appropriate technology provides an excellent setting for engineering design challenges. The following problem statement will provide a solid context in which students can apply what they learn about water, conflict, and technology—and appropriate technology.

**Problem Statement for Appropriate Technology Design Challenge**

A Haitian student has developed gastric pains. He seems to always have a low-grade fever and cannot concentrate in school. He is not able to contribute to his family’s income. He has even tried to grow a garden, but it always seems to die. The water that he carries for the garden is the same water he drinks. He has asked a neighbor for well water, but she will not provide it.

Provide students resources that lead them to determine that water quality could be one of the Haitian student’s problems.
and lead them toward appropriate technology solutions for the Haitian context. In engineering teams, among other solutions, students can design slow sand filtration to clean local pond water and use the “purified” water for vegetable beds on school grounds. Work with the biology teacher. An excellent resource to Google is Ray and Jain’s Drinking Water Treatment: Focusing on Appropriate Technology (2011).

REFERENCES


ACKNOWLEDGEMENT

Special thanks to Jerry Apple, of Applefield Farms, in Ruffin, North Carolina for access to his “center-pivot overhead rolling sprinkler” photograph in this article.

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A STEM-BASED, HIGH SCHOOL AVIATION COURSE

BACKGROUND

In the fall of 2008 I was hired as a high school technology teacher with a teaching emphasis in advanced manufacturing and CNC. Shortly after that time the school district instituted additional requirements for fundamental courses like math and English in preparation for a new round of high-stakes testing in Pennsylvania, similar to what is occurring throughout the nation. This resulted in a decrease in all students’ ability to select elective courses. The increased requirement in fundamental courses raised concerns for our entire department and me in particular as “low man on the totem pole.” We were faced with a decreasing population to draw from and increased pressure to make significant contributions to bolstering mandatory test scores in core subjects, and I was the most likely faculty member to suffer the consequences if we didn’t right the ship. I decided to explore topics that would allow me to continue teaching about technologies that I love in a way that would undeniably make contributions to basic skills and STEM subjects in particular. The course I settled on developing was a half-year course in aviation technology.

Many aviation curricula were reviewed and analyzed to tailor this course to best meet the needs of the students, school, and community. Rather than just an overview of how aircraft work, or just a course on how to fly, we instead attempted to provide a well-rounded approach to instructing students in this area that represented a culmination of the many facets of flight technology. Vocational training was not a goal; however, exposure and understanding of the careers and opportunities that aviation holds were goals since, without exposure to careers and the skills required in industry, it is difficult for young people to choose a career path after high school. A curriculum outline was created based upon the goals established and ultimately implemented. Each major unit of study was assessed with a written test and, in the case of manipulative skills, a manipulative test was also administered.

KNOWLEDGE AND EQUIPMENT NECESSARY

With few exceptions, most commonly available ground-school aviation curricula contain similar information. Typically the main focus is to teach about items associated with becoming an entry-
level pilot and passing the ground-school portion of a pilot test known as the FAA Airman Knowledge Test. Courses such as the Cessna Flight Training Curriculum or Sporty’s Learn to Fly Course are available for purchase online or through a local flight school. They start with the basics, such as forces that act upon an aircraft in flight, and progress into more complex topics, such as instrumentation, weather, and flight planning. Anyone planning to teach a high school aviation class would benefit from completing such a course, with costs ranging from about $200–$350. The information is generally provided on DVDs or through a website that is accessible with a password. However, the intent of a high school aviation course should not focus exclusively on pilot training. Therefore, the information gained from a flight-training course should be supplemented with additional information about the rich history of aviation along with the broad array of careers associated with aviation, such as air traffic control, aircraft maintenance, and airport administration, in addition to the various aspects of piloting. Additionally, concepts should be reinforced through hands-on activities where possible. The most obvious activity is simulated flight training, with the use of programs such as Microsoft’s Flight Simulator X that is available for $25-$30 per seat. The simulation aircraft can be controlled through the use of keystrokes on the keyboard, but you will likely want to invest in yokes and foot pedals that interface with the computers for more realistic simulations. The yoke and rudder pedals are much more realistic for training than the keyboard, but they are expensive, usually costing about $200–$350 per set.

Some plotters, E6-B flight computers, and laminated charts will be required for students to learn to plan flights. These items typically only cost about $20 apiece. Lastly, a visit to a local airport, including access to the control tower, would make for an ideal field trip. The total cost of implementing the course was approximately $4000 with the use of existing computers. While it may sound like a big expense, unlike the majority of our other course offerings, this course uses almost no consumable supplies, and the equipment should last for years to come if treated properly.

CONTENT AND ACTIVITIES

The course was comprised of five units of aviation theory. Manipulative flight competencies were also taught during these units and tested throughout the course. These manipulative competencies are listed, along with the major academic units. The content outline of this course is as follows:

1. **Unit One – Introduction to the Aviation Industry**
   a. History of Aviation
   b. Careers in Aviation
   c. Types of Aircraft
   d. Pilot Ratings and Cost of Training

2. **Unit Two – Aircraft Systems**
   a. Aircraft Parts
   b. How a Wing Creates Lift
   c. Engine Parts and Operation
   d. Aircraft Systems
3. **Unit Three – Instrumentation**
   a. Pitot-Static
   b. Gyroscopic
   c. Magnetic

4. **Straight and Level Flight and Turns Manipulative Instruction**
   a. Roll
   b. Yaw
   c. Pitch
   d. Throttle
   e. Heading

5. **Unit Four – Safety and Airport Procedures**
   a. Flight Safety
   b. Airport Markings and Traffic Patterns

6. **Unit Five – Weather**
   a. Weather Phenomena
   b. Forecasts
   c. Reports
   d. How Weather Affects Flight

7. **Solo Manipulative Flight**
   a. Instrumentation
   b. Takeoff
   c. Flying Straight and Level
   d. Climbs and Descents
   e. Slow Flight
   f. Coordinated Turns
   g. Landing

8. **Cross-Country Summative Project**
   a. Use of the E6B flight Calculator
   b. Payload Calculations
   c. Fuel Calculations
   d. Preflight Safety Check

**SUMMARY AND CONCLUSIONS**

Despite a reduction in the number of elective slots, it is possible to develop new STEM-based courses that will attract enrollment into high school technology and engineering programs. The aviation course described in this article is one such example. The course managed to attract enough students to fill four 20-student sections per year in the first year it was offered. Enrollment was more than twice what was anticipated. Furthermore, another 40 students enrolled in the course in the second year. The course cost approximately $4000 in software and equipment to implement with the use of existing computers, but it required almost no consumable materials and should last for many years without requiring much supplemental equipment.

During the course, the students completed five units of instruction, spanning all aspects of aviation from history through career exploration, with an emphasis on principles of flight and piloting. Data collection and analysis indicated that the students enjoyed the practical aspects of flight training with the computer simulation software more than any other unit of instruction. The data also indicated that the students had the most difficulty comprehending the unit on flight instrumentation. As a result, more emphasis should be placed on instrumentation, as this area is so critical for safe flight. Increased emphasis could be done through experiments with atmospheric pressures and other hands-on activities that would pique interest and add concrete examples for students to draw upon in order to better understand some theories and laws. Additionally, collaboration with the science and math departments could be implemented in order to address areas that students were not as proficient with during standardized testing. By giving students a perspective on difficult concepts through concrete examples and including activities that are fun, they may understand and retain these concepts with greater confidence and enthusiasm.

In conclusion, the research, creation, and implementation of this course were considered a success. The majority of enrolled students went from knowing very little about aviation to understanding the history, career opportunities, aircraft systems, instrumentation, basic aircraft control, weather, and flight planning associated with piloting and actual flight. The Technology Education Department now has another course to offer that attracts a large number of students annually and increases the diversity of those enrolling in what had been a traditionally materials-based program.

**REFERENCES**

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This article is based on a master’s thesis recently completed by Alex Surra and supervised by Len Litowitz.
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CLASSROOM CHALLENGE

How does a plastic bridge differ from the construction of a traditional wooden timber bridge?

MISSION

Your small municipality needs to replace a bridge that spans a classic creek about fourteen feet wide. The creek is in a scenic part of the downtown area: a public space, where workers and citizens relax and have lunch year-round. Being a “green” community, the town leaders would like to use recycled materials as much as possible in the making of this bridge and any associated structures. Ideally, you and your design team should plan on using recycled plastic materials. Bridge traffic and loadings likely will be restricted to pedestrian foot traffic and golf-cart-like maintenance/trash pickup vehicles. A key concern is to ensure that the bridge blends in with the natural earth tones of the park. How would you do it?

IMPLEMENTATION

Over the last decade or so, plastic building materials have been available and used in a variety of applications. Empower your students to look into the availability of plastic recycled materials that are made into building materials; specifically, what are their:

- Shapes
- Dimensions
- Colors
- Plastic composition
- Weight
- Strength capabilities
- Ability to be connected using traditional fastening materials
- Weathering and endurance to temperature changes
- Color trueness after weather exposure
- Rot resistance
- Expected lifetime

Identify those materials that manufacturers can reasonably provide and, if possible, obtain samples of the materials for examination. You and your team may want to visit some sites to see how the materials appear after some years of exposure to the elements. Ask the manufacturers where sites using their products may exist. Check with other towns that may have undertaken such projects. Contact your town’s recycling staff to see if they can recommend some places to visit or manufacturers they are aware of. If the materials manufacturer is nearby, you may want to visit its facilities or invite a speaker in from that company to address your class about how its products have been used.
Now, design a simple bridge to span the 14-foot creek bed and accommodate the vehicle and pedestrian traffic. Have a number of student teams come up with their own designs and foster a spirit of competition in this activity. Encourage the student teams to be both functional and aesthetic in their designs, reminding them of the popularity of this site to downtown workers, visitors, and citizens. Beforehand, you may want to create a simple diagram showing how the hypothetical creek is situated and where the creek crossing is to be made so students have some reference point from which to begin.

How strong should the bridge be? This is a good place to bring in some discussion about structures and how engineers design structures such as bridges, ramps, and walkways. What building components for the bridge will be needed, including number and size?

Have students make a bill of materials for the bridge: all the components needed to purchase and build the bridge on-site. This is a great test of their planning and organizational skills, which are tremendously important in the business world. Students can use spreadsheet programs to create a list of materials needed. Who will build the bridge...town workers, private contractors, the plastics manufacturer?

How much will it cost, and how long will it take to build the bridge? Examine the issues involved as the old bridge is removed and the new one put in place. Will there be special procedures that need to be implemented to ensure safety to the public as the bridge removal and replacement is underway?

How does a plastic bridge differ from the construction of a traditional wooden timber bridge? Are there special concerns involved with the construction process? Is there a need for special...
Once you have completed this exercise, maybe there is the possibility that the student designs could be implemented in one of your town’s parks or public spaces!

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town permits, inspections, or approvals? Are there any possibilities of things chemically leaching out of the plastic materials that could pollute the soil near the creek or the creek itself?

How would your students address the footings of the bridge? Should they plan for the creek to be swollen with flood waters, possibly compromising the strength of the bridge footings? If so, how does this affect the design of the bridge? Has such flooding ever occurred before? Are there other weather/environmental concerns that could impact bridge design and construction?

Evaluate the final costs to purchase and ship the materials to the park site and the manpower needed to assemble it.

Encourage your students also to consider additional uses of recycled plastic that could be made into objects placed near the bridge that complement the beauty and functionality of the bridge…things like park benches, tables, trash disposal receptacles, etc.

What additional uses of recycled plastic can be made into objects near your bridge? 

Photo credit: Wikimedia Commons.
**Scratch, Sensors, and Homemade Devices Working Together**  
(Wednesday, March 25, 1:00pm-4:00pm)  
In this standards-based session, participants will use the “free” software, Scratch (visual programming environment), sensors, and homemade devices to incorporate interactivity into programs. The key goal of this session is to demonstrate how each area—Science, Technology, Engineering, Art, and Mathematics—have applications using sensors with Scratch. The integration of electronics enhances tactile experiences along with visual learning, therefore addressing diverse learning styles.

**Examining Laboratory Safety Through an Integrative STEM Education Activity**  
(Wednesday, March 25, 1:00pm-4:00pm)  
Dive into this content-rich engineering design challenge used to intentionally integrate multiple disciplines and discuss safer methods for teaching Integrative STEM Education activities. Participants will be immersed in The Ocean Platform Engineering Design Challenge, which was used to professionally develop teachers attending the VISTA program at Virginia Tech. This Challenge can be used to intentionally teach STEM, history, language arts, and other content areas concurrently, while providing students with an authentic hands-on learning experience. Participants will safely design a solution to this engineering design challenge, which is suitable for upper elementary to high school students. Additionally, this activity will provide the foundation to examine safer practices for Integrative STEM Education laboratories.

**Elementary STEM Literacy Workshop**  
(Wednesday, March 25, 1:00pm-4:00pm)  
Participants will investigate why STEM literacy is essential for students in Grades K-6. It ultimately affects our economic success and the elementary child’s present and future success in an increasingly technologically dependent world. The engineering design process will be modeled as a problem-solving tool for students and as a teaching guide for teachers. The relationship between scientific inquiry and engineering design will be discussed. Participants will also engage in standards-based, hands-on activities that correlate to national science standards and the K-6 curriculum.

**Hybrid Training Opportunity at the 2015 ITEEA Conference**  
(Wednesday, March 25, 9:00am-5:00pm)  
ITEEA is pleased to provide an opportunity to participate in a hybrid training course for WaterBotics®—a rich and exciting underwater robotics project that uses LEGO® building materials and programming environments. Stevens Institute of Technology is offering the course, which will commence with the full-day workshop in Milwaukee, followed by 1-4 online modules, 2-3 hours each, offered shortly after the conference. All participants will receive a $100 stipend upon completion of the face-to-face preconference workshop to help offset costs. Preregistration is required.

**High School EbDLab™: PathwayExtension™ – Robotics, Engineering, and Automation**  
(Saturday, March 28, 8:30am-4:00pm)  
This High School EbDLab™ provides hands-on instruction for teachers and administrators on the new EbD Pathway Extension in Robotics, Engineering, and Automation. During the full-day session, participants build, program, and compete with robots using the same blended-learning curriculum featured in EbD’s Robotics PathwayExtension. Participants will also learn how the Robotics PathwayExtension provides a comprehensive study of engineering concepts, including physics, programming, mechanical systems, electrical and electronics systems.

In addition to workshop experiences, the ITEEA Milwaukee conference also offers dozens of professional development sessions, tours, the latest product offerings, the STEM Showcase, and MUCH more! Learn more by viewing the preliminary program at [www.iteea.org/Conference/precon.pdf](http://www.iteea.org/Conference/precon.pdf). Workshops carry additional fees.

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“I found myself spending a ton of time on the discussion boards, and actually having a hard time ‘turning off’ my courses. I was more invested and more connected with my professors and my classmates, and spent more time on my education than I would have if I had been in a traditional classroom.”

— Kristy Rhodes, master’s in technology education, class of 2010

These 30-credit-hour programs do not provide initial teacher licensure.