



**Special
Issue:
Who Are We?**



ENGAGING AND EMPOWERING DECISION MAKERS THROUGH INTEGRATIVE STEM EDUCATION

The annual ITEEA conference provides an unparalleled opportunity for technology and engineering educators to gain comprehensive professional development and networking experiences. ITEEA members pay a reduced rate to attend and can choose from dozens of interest sessions, workshops, and social events. This is a unique opportunity to learn from and share with other technology and engineering STEM education professionals in a variety of formats.

2017 ITEEA CONFERENCE HIGHLIGHTS

ITEEA STEM Showcase - Highlighting Best Practices Through Integrative STEM Education!

The ITEEA STEM Showcase features an idea, technique, or best practice related to learning activities, marketing materials, career guidance, facility design, program design, assessment methods, equity, or classroom and laboratory management techniques. Showcasers illustrate a single element of technology or engineering teaching and learning that they feel they have exemplified. Attendees are invited to join ITEEA in the exhibit area for our Celebration Reception immediately following the STEM Showcase.

Administrator I-STEM Education Professional Development Strand

Bring your Administrator at no additional cost (sponsored registration). A special strand of presentations will be offered that are designed for Administrators to build understanding and support for your program!

Teacher Leadership Workshop Opportunities

Prior to the official start of the ITEEA conference, take advantage of a variety of workshop opportunities. Experienced presenters will share their knowledge on topics such as The Essentials of Backward Design Planning, STEAM Education, Design Thinking in Integrated STEM Education, and STEM Strategies for the Elementary Classroom. Workshops fill quickly, so sign up today!

Keynote Speaker Steve Culivan

Steve Culivan is A NASA Education Professional Development Collaborative Specialist at the John C. Stennis Space Center in Mississippi where he develops and provides NASA STEM online and face-to-face professional development for teachers. He is a former classroom teacher who will speak on the topic of "Technology and Engineering Through the Eyes of NASA."

Awards Brunch Motivational Speaker: Lyndy Phillips

"Laugh More. Stress Less."

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STEAM Strand and Preconference Workshop

ITEEA is pleased to announce a dedicated STEAM strand in 2017! More information will be coming soon for those interested in these specialized sessions on how Technology/Engineering/STEM can provide the "what and how" to the contextual "who and why" of the fields of the Arts—as integrated with the subjects of Design, Society, Language, Music, and Physical Education. There will be a preconference workshop for PD credits as well as STEAM sessions related to setting up programs, theory and research roundtables, and workshops with projects.

PREREGISTRATION IS NOW OPEN

Go to www.iteea.org/Registration_2017.aspx for details.

For complete conference information, visit the ITEEA website at www.iteea.org/ITEEA_Conference_2017.aspx.

PREREGISTRATION DISCOUNTS

Register prior to February 15, 2017 and save 15% on conference registration fees. Preregistration pricing is \$360 for ITEEA members and \$485 for nonmembers. After February 15, full conference rates of \$430 for members and \$540 for nonmembers will apply. www.iteea.org/Registration_2017.aspx

PREREGISTRATION PRIZE DRAWINGS

Names of those registered by February 15 will be entered into drawings for a \$100 Amazon Gift Card. Drawings will be held at the General Sessions on Wednesday and Thursday mornings. You must be present to win.



PROFESSIONAL DEVELOPMENT LEARNING SESSION HIGHLIGHTS

Over 100 Professional Development Learning Sessions will be conducted at this year's conference. Most sessions are 50 minutes in length and occur on Thursday, Friday, and Saturday. Listed below are a few highlights of each day; the complete list of session titles will appear in the full conference program.

Thursday

- Using Scientific Evidence to Drive Engineering Design
- Engaging and Teaching Through Service Learning
- Launching STEAM Activities Through Differentiated Instruction
- Middle School Students as Designers, Makers, and Creators!
- Technology Engineering Labs for the Future
- Teaching Design Using Gender-Neutral Assignments
- The Essentials of Backward Design Planning

Friday

- NGSS: Preparing Students for STEM Careers
- Engineering FUSION: Finding Unique Strategies to Involve Organizations and Networks to Promote Engineering
- Manufacturing and Free Enterprise Activity: Mag-Lev Tracks
- How I Started an Elementary Engineering Program
- Affordable Robotics and Integrated STEM for ALL
- Decoding Coding: Drones and Microcontrollers
- Using STEM with Future Teachers

- Teamwork in Engineering
- Girls Just Want to Do STEM

Saturday

- Teaching Soft Skills in Technology and Engineering
- Phenomenal Family STEM Events
- Experiential Learning: Engaging Students in Design Projects
- Creating Local STEM Competitions Using TSA Activities
- STEM on a Shoestring

The 2017 Conference will also feature panel sessions, providing a variety of perspectives on the following topics:

- Who Are We?
- On Your Mark – Get Set – Go!: STEM Competitions
- Teaching Content Literacy in STEM
- Connecting With Your Community Through STEM
- The Maker Movement and Technology & Engineering Education
- Enriching the STEM Experience Through Classroom Diversity
- Teaching Nontraditional Students

STEM LEADERSHIP WORKSHOPS

- The Essentials of Backward Design Planning
- Homemade Game Devices at the Next Level
- Design Thinking in Integrated STEM Education
- STEM Strategies for the Elementary Classroom
- STEAM Education Professional Development Workshop

EDUCATIONAL TOURS

- AT&T Stadium Tour
- Globe Life Park
- Fire Training Research Center
- C. R. Smith Museum
- George W. Bush Library
- Frontiers of Flight Museum

ENGINEERING BYDESIGN LABS™

Thursday

Middle School: *Engineering for All–Food* and *Engineering for All–Water*

Middle School: *Invention and Innovation*

High School: *Foundations of Technology*

Friday

High School: *Engineering Design*

Middle School: *Technological Systems*

Elementary: *Ebd-TEEMS™: Grades K-6*

AND MUCH MORE...

- Program and Teacher Excellence General Sessions
- I-STEM Education PreK-12 Sponsored Administrator Strand
- PATT International Sessions
- TEECA Competitive Events
- ITEEA STEM Showcase
- Action Labs
- Exhibits
- Celebration Reception
- Meal Events
- Networking

LOGISTICS

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Be sure to identify yourself as attending the ITEEA conference to get the conference rate.

**THE ROOM BLOCK CUT-OFF DATE IS:
Wednesday, February 10, 2017.**



contents

technology and engineering teacher

VOLUME 76 ISSUE 4



features

A PROPOSITION TO ENGINEER A BRIDGE: RECONNECTING WITH THE INDUSTRY-BASED EDUCATORS P.9

The realities of our society and the nationwide emphasis on college and career readiness have demonstrated that there are components of the former industrial arts curriculum that still hold significance to local communities.

By Kenny Rigler

TECHNOLOGICAL LITERACY: THE PROPER FOCUS TO EDUCATE ALL STUDENTS P.13

Technological literacy is the right focus for the future because it provides an opportunity for T&E education to reach more students, not just those interested in specific vocational skills or becoming professional engineers.

By Thomas Loveland, DTE, and Tyler Love

ENGINEERING EDUCATION: A CLEAR DECISION P.18

The authors assert that there is only one viable pathway for the field—to recast itself as P-12 Engineering Education.

By Greg J. Strimel, Michael E. Grubbs, and John G. Wells

departments

ON THE ITEEA WEBSITE P.5

STEM EDUCATION CALENDAR P.6

STEM EDUCATION NEWS P.7

EDITORIAL: WHO ARE WE? P.8

RESOURCES IN TECHNOLOGY AND ENGINEERING P.25

SAFETY SPOTLIGHT P.38

CLASSROOM CHALLENGE P.40

THE SUPPLY AND DEMAND OF TECHNOLOGY AND ENGINEERING TEACHERS IN THE UNITED STATES: WHO REALLY KNOWS? P.32

The purpose of this study was to determine the supply and demand of technology and engineering teachers in the U.S. and compare resulting data to previous studies to determine trends.

By Johnny J Moyer, DTE

Conference Preregistration Deadline is February 15, 2017!



February 15, 2017 is the deadline to preregister for ITEEA's 79th Annual Conference in Dallas, TX on March 16-18, 2017. After February 15, full conference rates will apply. Don't be late, or you'll miss the advantages.

- Save nearly 20% on your registration.
- Receive access to all conference programming through ITEEA's mobile app.
- Have your packet ready for you when you arrive. No waiting!
- Be eligible to win a \$100 Amazon gift card for preregistered attendees.
- Secure your housing to receive ITEEA's discounted room-block rate. ITEEA's hotel room block is limited.

See conference, registration, and housing information at www.iteea.org/ITEEA_Conference_2017.aspx

The New ITEEA Mobile App is Coming!



Prior to the 2017 conference you will be able to download the official ITEEA mobile app to access events, speaker information, exhibitors, and much more! The new and improved 2017 app will guarantee less walking and keep your day structured, all from the palm of your hand:

- Detailed agenda at your fingertips.
- Meeting room and exhibit floor maps.
- Cyber networking – including speakers and exhibitors.
- Polls, surveys, and more.
- Browse exhibitors, mark your favorites, route to various booths, take notes on them, and more!
- Interactively add sessions from the app to your custom app schedule, then sync across your multiple devices!
- Stay up-to-date with real-time alerts.
- Follow the social media buzz; even tweet from the app #iteea2017!
- Browse local Dallas restaurants, things to do, and sights to see and reference helpful travel information and much more!

More information will be sent to all registered attendees after February 15!



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December 1, 2016

Application deadline for ITEEA Scholarships and Awards
www.iteea.org/AwardsScholarships.aspx

December 1, 2016

Application deadline for ITEEA's Distinguished Technology and Engineering Professional (DTE) and Emerging Leader (EL) Recognition Programs
www.iteea.org/Awards/dte.aspx
www.iteea.org/Awards/el.aspx

February 9-11, 2017

23rd Annual Space Exploration Educators Conference
Space Center Houston – Houston, TX
<http://spacecenterSEEC.org>
seec@spacecenter.org

February 1, 2017

Entry deadline – Engineer Girl Essay Contest: *Engineering and Animals*
<http://engineergirl.org/32376.aspx>

February 10, 2017

Housing deadline for ITEEA's 79th Annual Conference
March 16-18, 2017, Dallas, TX
www.iteea.org/Housing_2017.aspx

February 15, 2017

Preregistration deadline for ITEEA's 79th Annual Conference
March 16-18, 2017, Dallas, TX
www.iteea.org/Registration_2017.aspx

February 18-24, 2017

Future City Competition Finals
The Power of Public Space
Washington, DC
<http://futurecity.org/>

March 16-18, 2017

79th Annual ITEEA Conference
Engaging and Empowering Decision Makers Through Integrative STEM Education
Sheraton Dallas – Dallas, TX
www.iteea.org/40503.aspx

April 2, 2017

Girls STEM Summit – Statewide 2017
Regis – Weston, MA
juniortech.org

April 21-23, 2017

Kansas Association of Teachers of Science—KATS Kamp
<http://kats.org/kats-kamp/>

June 21-25, 2017

2017 National TSA Conference
Defining Your Future
Rosen Shingle Creek
Orlando, FL
<http://tsaweb.org/National-Conference>

June 25-28, 2017

American Society for Engineering Education (ASEE) 124th Annual Conference & Exposition
Where Engineering Education Takes Flight – From P-12 Through Life
Columbus, OH
<https://www.asee.org/conferences-and-events/conferences/annual-conference/2017>

July 10-14, 2017

PATT 2017
Technology & Engineering Education – Fostering the Creativity of Youth Around The Globe
Arch Street Meeting House
Philadelphia, PA
www.studentservicesinc.com/ticket-sales/patt/

technology and engineering TEACHER

EDITORIAL POLICY

As the only national and international association dedicated solely to the development and improvement of technology and engineering education, ITEEA seeks to provide an open forum for the free exchange of relevant ideas relating to technology and engineering education.

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.

REFEREE POLICY

All professional articles in *Technology and Engineering Teacher* are refereed, with the exception of selected association activities and reports, and invited articles. Refereed articles are reviewed and approved by the Editorial Board before publication in *Technology and Engineering Teacher*. Articles with bylines will be identified as either refereed or invited unless written by ITEEA officers on association activities or policies.

TO SUBMIT ARTICLES

All articles should be sent directly to the Editor-in-Chief, International Technology and Engineering Educators Association.

Please submit articles and photographs via email to kdelpaz@iteea.org. Maximum length for manuscripts is eight pages. Manuscripts should be prepared following the style specified in the *Publications Manual of the American Psychological Association, Sixth Edition*.

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Save 15% by registering before February 15, 2017. Make plans now to join your professional colleagues at the Sheraton Dallas in 2017. Information can be found at www.iteea.org/ITEEA_Conference_2017.aspx.

To register, go to www.iteea.org/Registration_2017.aspx.



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 at the ITEEA Dallas conference in March are:



**President-Elect:
Yvonne Spicer, DTE**

Yvonne is Vice President of Advocacy and Educational

Partnerships at the National Center for Technological Literacy in Boston, MA.



**Region I Director:
Debra E. Shapiro**

Debra is a Technology and Engineering Educator at Forest

Glen Middle School in Suffolk, VA.



**Region III Director:
Kurt R. Helgeson**

Kurt is a Professor and Department Chair at St. Cloud

State University in St. Cloud, MN.

Also joining the ITEEA Board of Directors in March are:



CSL Director: Mark Crenshaw

Mark is CEO Hart College and Career Academy - CTAE Director for the Hart County Charter System in Hartwell, GA.

He will represent the Council for Supervision and Leadership (CSL).



TEECA Director: Scott Greenhalgh

Scott is an Assistant Professor and Program Coordinator of Technology and Engineering Education at the University of Northern Iowa in Cedar Falls, IA. Scott will represent the Technology and Engineering Education Collegiate Association (TEECA).

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 a part of the ballot, each of the candidates has demonstrated leadership in the field.

Best STEM Books for K-12

In early December, NSTA will release a reviewed list of books containing the best STEM content for K-12. The list was determined by a panel of reviewers, which included ITEEA members Sharon Brusich of Millersville University and Thomas Roberts of the University of Kentucky. Both Sharon and Thomas are contributing members of ITEEA's Children's Council. Be sure to check www.nsta.org/publications/stembooks/ to see the list once it's released.

Sharon and Thomas will be delivering a presentation and participating in a STEM Showcase on the Best STEM Books at ITEEA's 2017 Conference in Dallas.

Manage Your ITEEA Profile

Did you know you can "manage" your profile on the ITEEA website? Your profile is what others see when they search your name on our site. Upload your bio and your photo, designate your affiliation, and update your contact information. You can make your information public or private. You can also change your password and request a new username. Your profile has links to your IdeaGarden posts, your downloads, your invoices, and your renewal form. You're in charge of your ITEEA profile! Click the green login button at www.iteea.org and log in. Now click the Manage Profile button.

who are we?

You don't have to have been part of the field we now refer to as Technology and Engineering Education for very long to know that it has always experienced what might be termed an "identity crisis." Not only does Technology and Engineering Education struggle with how it is perceived by those outside the field, the problem is endemic. Even those who are part of the field have differing opinions regarding what they have taught, what they teach now, and what they will teach in the future.

In this special issue of *Technology and Engineering Teacher*, we highlight three different interpretations of "who we are." The viewpoints range from proposing a greater appreciation for industrial arts to completely rebranding the field as engineering education. They are by no means the only perspectives, but each provides a great deal of food for thought.

In "A Proposition to Engineering a Bridge: Reconnecting with the Industry-Based Educators," the author suggests that "the realities of our society and the nationwide emphasis on college and career readiness have demonstrated that there are components of the former industrial arts curriculum that still hold significance to local communities." More importantly, the notion is put forth that it is time for a stronger connection between industrial education and technology and engineering education.

"Technological Literacy: The Proper Focus to Educate ALL Students" strongly supports the concept of paying homage to our design-based roots but also providing "rigorous instruction that applies STEM skills and situates it as a valuable stakeholder among the core content areas." The



viewpoint also recognizes the importance of reaching additional students, rather than only those interested in vocational or engineering careers.

In "Engineering Education: A Clear Decision," the authors make a strong case for "recasting" Technology and Engineering Education as P-12 Engineering Education. In so doing, it is asserted that students will gain valuable skills as well as a clear path to continued study, while the field itself would gain greater public understanding, resulting in additional support and acceptance.

As with all of the articles provided for you within *Technology and Engineering Teacher*, we hope this special issue will inspire further thought and conversation. In fact, we have scheduled a special panel presentation with the authors of all three viewpoints on Thursday, March 16 at 1:00 pm at ITEEA's Annual Conference in Dallas, TX. Hope to see you there!



Kathleen (Katie) de la Paz is ITEEA's Editor-in-Chief and Director of Communications. She can be reached at kdelapaz@iteea.org.

by
**Kathleen B.
de la Paz**



a proposition to engineer a bridge:

reconnecting with the industry-based educators

Now is a time for the association to make an organized effort to engineer and construct a bridge between the two communities of technology and engineering education and industrial education.

Even thirty years after the International Technology and Engineering Educators Association (ITEEA) retired its discipline name as industrial arts (Foster & Wright, 1996), there are still a significant number of educators who refer to themselves as industrial arts or industrial technology teachers (Spencer & Rogers, 2006). Even more importantly, there are still a significant number who currently teach a traditional industrial-based curriculum within their programs—with full support from their administration and community (Kelley & Wicklein, 2009). However,

in terms of representation within ITEEA, there are very few who identify themselves as industrial educators, and since the 1980s there has been a significant decline in the number of industrial-based presentations at the annual conferences (Reed & LaPorte, 2015).

Some may assume the majority of industrial educators have transitioned along with ITEEA away from an industrial-arts-based curriculum and migrated toward tech-

by
Kenny Rigler

nology and engineering education. However, a careful examination of the literature and an even further look at the local school districts would demonstrate a very different story. The literature over the past three decades has confirmed:

- "This study's findings indicate that technology educators strongly support traditional industrial arts" (Kraft, 2001, p. 54).
- "Though no states reported using the term 'industrial arts' or 'industrial education' for technology education, when asked if traditional industrial arts and technology education operated concurrently, 34 of 39 states reported yes" (Akmal, Oaks, & Barker, 2002, p. 17).
- "The data seem to suggest that while many support technological literacy, design, and engineering as major components of an undergraduate program, an almost equal number resist this idea and prefer an undergraduate program that revolves around more traditional industrial curriculum organizers" (Daugherty, 2005, p. 57).
- "It appears that the field of technology education has not moved far from its industrial arts roots" (Kelley & Wicklein, 2009, p. 17).

So if the industrial educators are still in existence, why are they no longer well represented within ITEEA? Have the educators joined another association that more closely aligns with their beliefs and values of technical learning through skills development in using tools and machines? Or are they no longer connected with a national association and instead operating in isolation within their local communities?

ITEEA has made significant gains over the past two decades and should be commended for its work in technology and engineering literacy. Through its recent STEM initiatives, the discipline has made significant progress in its century-long effort to be incorporated into the general education program within school districts, especially at the elementary and middle school levels. This article is not a proposition to return back to the industrial heritage. It is, however, an effort to shine a light on the fact that, over the past three decades, ITEEA has failed to create a connection with its foundational core and in so doing has disenfranchised the very community upon which it was built and thereby limited its possible integration in the local school districts, especially at the secondary level.

There may have been a time when it seemed the industrial curriculum had lost its relevance, and in order to make a successful transition to technology education it was necessary for the organization to make a distinction between the two (Volk, 1996). But now, after 30 years, the realities of our society and the nationwide emphasis on college and career readiness have demonstrated that there are components of the former industrial arts curriculum that still hold significance to local communities. Ad-

ditionally, the local industrial educators have found a way to persevere even without support at the national level. If the industrial arts-based curriculum and educators are here to stay, now is the time for the association to make an organized effort to engineer and construct a bridge between the two communities of technology and engineering education and industrial education.

Importance of Technology and Engineering Literacy

This is not to suggest that the association should discontinue its efforts regarding technology and engineering education. The curricular focus of STEM is an effective and appropriate effort, especially in the current educational landscape. The emphasis on technological and engineering literacy is a timely and effective vision for the association. But this is a call for the professional community to consider the possibilities of teaching technology and engineering literacy within an industrial education environment. This, rather than previous efforts that expected every educator to abandon industry-based curriculum and replace it with a broad-based technology and engineering curriculum, typically including some type of modular learning environment (Carter, 2013; Weymer, 2002). Though these environments may have worked for some, there are a significant number of educators and districts that prefer an industry-based curriculum and need support with integrating technology and engineering literacy into their current curriculum, rather than recommendations to completely change it into something different.

Recent efforts to incorporate STEM into the discipline are not necessarily new. One of the first formalized curriculums related to engineering education was the Principles of Technology (PT) program developed in the mid-1980s by the Center for Occupational Research and Development in Waco, Texas (Dugger & Johnson, 1992). The PT program attempted to integrate skill-based vocational educational courses with knowledge-based physics courses by utilizing an interdisciplinary approach combining technology, applied physics, and applied mathematics (Dugger & Meier; 1994). The result was the development of a two-year sequence of applied physics courses that taught physics concepts through project-based learning. The PT program was intended to draw students who would normally follow the vocational education track and allow them to learn physics-based principles through hands-on learning opportunities.

Then, in the 1990s, another comprehensive secondary-level engineering education program was developed called Project Lead the Way (PLTW). Similar to the PT program, PLTW was designed as a curriculum to bridge the gap between traditional technical courses and academic courses. The program combined a high level of academic rigor with hands-on classroom experiences related to the engineering education field (Brophy, Klein, Portsmouth, & Rogers, 2008). The PLTW program was designed

as a four-year sequence of courses that included foundational courses during the first year, specialization courses during the second and third years, and a capstone course during the fourth year (Brophy et al., 2008).

ITEEA's Engineering byDesign™ (EbD™) curriculum was developed through the efforts of its Center to Advance the Teaching of Technology and Science beginning in 2004 (ITEA, 2006). The curriculum has been promoted as a standards-based solution for teaching technology and engineering literacy in Grades K-12 and provides daily projects, activities, and discussions in the areas of construction, manufacturing, information and communication, transportation, and power and energy (Walach, 2015). At the elementary level, the curriculum creates connections between the various STEM areas and emphasizes invention, innovation, and inquiry. At the middle school level, the curriculum allows students to explore the various areas of technology and systems and continue advancing in invention and innovation. Then, at the high school level, the curriculum provides greater depth and experiences in the foundational areas of technology, technology and society, and technological design (ITEEA, 2016).

Though these types of programs have many strengths, they have not necessarily met the needs of the educators and districts that desire to offer an industry-based program and therefore have lacked relevance and appeal to industrial educators. Further, similar to the modular efforts, the programs typically expect a transformational change away from industry-based curriculum, whereas some educators and districts desire to maintain the hands-on, skill-based, and project-oriented nature of the traditional industry-based programs. Though there is evidence of the adoption of the various STEM-based programs across the nation, the strong existence of industry-based programs has demonstrated the need for another solution in order to effectively attract the attention of the industrial-based community.

Engineering a Bridge

The first steps in the engineering design process are to identify and define the problem (Eide, Jenison, Mashaw, & Northup, 2001). The primary purpose of this article is to highlight the problem that has existed for the past three decades (a disconnect between industrial educators and proponents of technological literacy) and to make a recommendation for ITEEA to begin the design process in engineering a bridge to reconnect with industrial arts and industrial technology educators. The construction of any significant bridge is a complex endeavor, and this proposition to build a bridge between technology and engineering education and industrial education will certainly require a multiyear effort from within and outside of the professional community.

Though not typically stated, another practical component of the "identify" and "define" stages of the engineering design process

is a rationale as to whether or not the problem is worth solving. There is no question that the half-century-old industrial education curriculum needs improvement. But change in education will most likely be evolutionary—as compared to revolutionary—and the proposed changes will need to align with the beliefs and values of the industrial education community. A high school instructor teaching six traditional classes of woodworking may not be giving his or her students the best opportunity to be successful in a future career. However, the students may be learning work ethic, creativity, problem-solving, and industrial skills that will most certainly be beneficial later in life. The key for a sustainable change effort is to begin embedding the project and skill-based nature of traditional shop classes with the science, technology, engineering, and math concepts that are important today—and that is a problem worth solving.

STEM Within an Industry-Based Program

There are a vast number of STEM concepts that could be incorporated into the design and production of a wood dresser, a metal trailer, or a set of architectural house plans. The solution, at least for the industrial community, is not to get rid of the shop projects and replace them with modular-type technologies and learning labs, but instead to develop and provide the professional development needed to learn and teach the STEM concepts related to the shop projects and provide practical examples for how to incorporate the STEM lessons into the industrial arts-based programs.

One area of similarity between industrial arts and technology and engineering education is the emphasis on design. The key difference between the two programs tends to be how the design process is taught and implemented within the curriculum. In industrial arts curriculum, design includes more of a trial-and-error process where the problem is identified, a solution is implemented, and evaluations are made on the success of the solution (Williams, 2010). On the other hand, the engineering design process incorporates more predictive mathematical analysis and optimization, particularly in the areas of statics, dynamics, thermodynamics, stresses, deflections, and loads (Eide, Jenison, Mashaw, & Northup, 2001; Williams, 2010). However, with the proper professional development and support materials, these STEM concepts could be incorporated into an industry-based program while still allowing the learning environment to incorporate traditional skill-based projects in the areas of woodworking, metals, and drafting/CAD.

Conclusion

The curricular focus of technology and engineering literacy is an effective and appropriate effort for ITEEA, especially in the current educational landscape. This call to action proposes that the ITEEA community consider the possibilities of teaching

technology and engineering literacy within an industrial-based curriculum and creating the professional development and learning materials needed to assist educators with integrating STEM concepts into an already established industrial arts or industrial technology program. Through this process, ITEEA may find another platform for teaching technology and engineering literacy, and the industrial education community may find the guidance, connectedness, and professional development it has needed for several decades. If this were to be achieved, the association could find a whole new community of educators looking for a national association to connect with and opportunities to engage in professional development. In working together—while embracing differences—the two communities may find they have more in common than they imagined and can accomplish so much more together than they ever could separately. It's time for the professional community to begin engineering a bridge.

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technological literacy: the proper focus to educate all students

The field should remain true to its hands-on, design-based roots but must also provide rigorous instruction that applies STEM skills and situates it as a valuable stakeholder among the core content areas.

Introduction

In the mid-1980s, leaders and members of the American Industrial Arts Association (AIAA) took a bold step to transition the field of industrial arts to technology education. Since 1986, numerous works (Savage and Sterry, 1990, ITEA, 1996) defining technology education have been published, with the central concept crystalized into the importance of teaching all Americans to be technologically literate. This focus culminated in 2000 with the release of *Standards for Technological Literacy: Content for the Study of Technology (STL)* by the International Technology Education Association (ITEA/ITEEA, 2000/2002/2007). The prior work and standards all coalesced to the technological literacy emphasis delivered

through various types of technology education courses. This inclusive approach has the goal of teaching technological literacy for all students to be college- and career-ready.

True to Our Roots, Yet Looking Ahead

Prior to the shift to technological literacy, industrial arts (IA) was the content area offered in secondary schools. The focus was on skills development, craftsmanship, and safety. IA was not job preparation with occupational skills; it was about developing in boys the basic tool skills and attitudes needed to contribute to

by
Thomas
Loveland, DTE
and Tyler Love

a technically and socially changing democratic society (Smith, 1973). Beginning in the 1960s and 1970s, though, enrollment in industrial arts began to decline, particularly in schools where it was offered as elective coursework. Educational leaders in the field began to lobby for refocusing industrial arts to stay current and remain viable.

Donald Maley proposed in *The Maryland Plan: A Junior High School Program in Industrial Arts* (Smith, 1973) and *Math/Science/Technology Projects for the Technology Teacher* (ITEA, 1985) that the goals of technology education should include applications of technology systems, nature, impacts and evolution of technology, problem solving using technology, technological and societal issues, use of technology resources, application of academic content including science, math, and language arts to solve problems, career information, and multicultural and gender diversity. These were revolutionary ideas in the early 1970s that were met with resistance; however, many of these overarching concepts found their way into *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007) and continue to influence what is taught today.

Other early calls for change came from the Industrial Arts Curriculum Project developed by The Ohio State University in the 1960s, American Industries Project, Jackson's Mill Industrial Arts Curriculum, and the Industrial Arts Programs Project at Virginia Polytechnic Institute and State University. ITEA released *A Conceptual Framework for Technology Education* (Savage & Sterry, 1990), which defined how human adaptive systems interacted with domains of knowledge. The impact of technology on this interaction led to new ideas on the technological method of problem solving; understanding of the resources of people, tools and machines, information, materials, energy, capital and time; and processes related to biotechnology, communication, production, and transportation technologies. A new definition of technology went beyond artifacts to include the processes and systems of technology.

With funding from the National Science Foundation and NASA, ITEA initiated the Technology for All Americans Project in 1994. The project was designed to determine what constitutes a technologically literate person and how technology education should be integrated into K-12 schools (National Research Council, 2002). Starting in 2000, ITEEA released multiple documents related to technological literacy: *Standards for Technological Literacy* (2000/2002/2007), *Advancing Excellence in Technological Literacy* (2003), and *Measuring Progress: Assessing Students for Technological Literacy* (2004). Technological literacy helped shift the focus of our field from primarily developing work skills in boys to teaching all students about technology. These solid foundational efforts paved the way for later curriculum shifts including Integrative STEM Education (Wells & Ernst, 2012/2015)

and engineering design without subsequent changes to the standards.

Characterizing Technological Literacy

Technological literacy “involves a vision where each citizen has a degree of knowledge about the nature, behavior, power, and consequences of technology from a broad perspective” (ITEA, 1996, p. 1). Ingerman and Collier-Reed (2011) stated that technological literacy is not a characteristic of an individual, but a characteristic of how one experiences and acts in relation to situations and technological processes while also considering societal engagement. According to ITEA/ITEEA (2000/2002/2007), a technologically literate person understands “what technology is, how it is created, and how it shapes society, and in turn is shaped by society” (p. 9). Collier-Reed (2008) later suggested that a technologically literate person could “understand the nature of technology, have a hands-on capability and capacity to interact with technological artifacts, and be able to think critically about issues relating to technology” (p. 24).

With the rapid technological changes in our society, technological literacy should be an enduring skill within each person. People will need to access information, solve problems, and make informed decisions about and with technology. Dugger (2000) stated that a “technologically literate person has the ability to use, manage, assess, and understand technology...(and) is comfortable with and objective about technology—neither scared of it or infatuated with it” (p. 10). Despite the varying expressions of technological literacy and its characteristics, it has remained the core of technology and engineering (T&E) education courses in many countries for a number of years.

Justification for a Technological Literacy Focus

Numerous research studies have suggested that there is a need to enhance the technological literacy of American citizens. One ITEEA Gallup Poll (Rose, Gallup, Dugger, & Starkweather, 2004) found that 63% of Americans believed engineering and technology were the same thing, and when asked what comes to mind when they heard the word technology, 68% of Americans indicated computers, while 5% specified electronics. These misconceptions of technology and engineering exemplify the need for T&E courses at the secondary level to prepare a more technologically literate citizenry. Seventy-four percent of Americans in the Gallup Poll shared a similar belief, stating that it was very important for people at all levels to develop some ability to understand and use technology. Additionally, 88% thought standardized science, math, and reading tests should include questions to determine how much students understand about technology. This became a reality in 2014 with the National Assessment of Educational Progress (NAEP) T&E Literacy (TEL) test. Approximately 21,500

American eighth grade students took this test, which examined the type and amount of T&E courses students completed, how often they spent time tinkering and troubleshooting both in and out of school, who taught them how to build and fix things, and T&E content questions. The results revealed that 48% of the eighth grade students reported never taking a T&E course, and 43% indicated they never took something apart to fix it and see how it works. Moreover, there were greater gaps in the amount of time spent outside of school by low income, minority, and female students trying to figure out how things work, how to fix things, building or testing models, and using different tools/materials/machines. It was found that schools helped reduce these disparities. Regarding the content questions, fewer than half (43%) of the students performed at or above the proficient level (Change the Equation, 2016). These findings indicate that, while many students are benefiting from middle and high school T&E education courses, there are still a significant number of students needing these classes to develop TEL proficiency.

Standards for Technological Literacy identifies seven subtopics of technology that were deemed worthy of standards and benchmarks to be taught in school systems: medical technologies, agriculture and related biotechnologies, energy and power, information and communication, transportation, manufacturing, and construction technologies. These broad, designed-world standards have provided states autonomy in defining which courses are eligible for technology education credit. Potential courses like gaming, television production, engineering, biotechnology, robotics, and others are very diverse, but all include students using the design process to solve open-ended problems. This variety of courses is a benefit to our field, as it allows states to focus on local and state needs while providing schools with the flexibility to offer programs taught by fully certified technology educators.

Applications in Technology and Engineering Classrooms

To demonstrate how T&E education looks as an inclusive approach rather than referring to the many ways that T&E education is commonly taught (e.g., AutoCAD, communication technology, power and transportation, robotics), the authors provide examples of how some states are choosing to teach technological literacy through courses that may be associated with other school content areas or are very new content programs.

The State of Florida declared in 2011 that all television production teachers had to hold technology education certification. Television production is often associated with the language arts electives of journalism or media studies, or as a vocational skills course for work in the broadcast television industry. Loveland and Harrison (2006) identified how a broader-based television production course could teach technological literacy through the design method, problem solving, use of changing technologies,



and communication of design solutions. Comprehensive projects could include public service announcements, commercials, documentaries, marketing videos, and music videos. This content area is a natural draw to high school students, resulting in booming enrollment.

North Carolina offers courses in Scientific and Technical Visualization, Game Art and Design, and Advanced Game Art and Design in its visualization curriculum strand in Technology Engineering and Design. These courses teach students how to solve problems using 2D and 3D animation software, use augmented reality as a visual and special tool, and conceptual and data-driven models to teach scientific, mathematical, technological, and engineering content for 21st century skills (Ernst & Clark, 2007).

Lazaros and Embree (2016) made the case for schools to offer biotechnology courses by reason of teaching students how to become technologically literate in biological research and technological breakthroughs. It was suggested that the best strategies included hands-on methods, the broader applications of biotechnology, and the use of computer modeling programs to simulate lab experiments. Furthermore, Wells (2016) found that biotechnology was naturally embedded across all five *STL* content categories and could be used to intentionally teach content and practices of both science and technology concurrently.

Asunda and Mativo (2016) reported that there are increasing numbers of engineering courses (Project Lead the Way, Engineering byDesign™) linked to academic courses. Despite this, most STEM content is still taught as mathematics and science with little connection to technology or engineering content. Based on *Standards for Technological Literacy* (ITEA/ITEEA, 2000/2002/2007), *Next Generation Science Standards* (NGSS Lead States, 2013) and *Common Core State Standards* (2014), they suggest that an integrative approach to teaching STEM should focus on active learning through engineering problem-



based activities focused on pragmatism and the constructs of systems thinking, situated learning, constructivism, and goal-orientation theory.

The examples described above provide opportunities for all students to enhance their level of technological literacy. Technological literacy encourages T&E educators to collaborate with English, biology, physics, and other teachers to enrich content from different disciplines and increase awareness of the relevance of our courses. Without these broad technological-literacy applications, our field could be viewed as an isolated content area among much larger disciplines.

Future Trends and Issues with Technological Literacy

Due to the timeless nature of the standards and benchmarks chosen (ITEA/ITEEA, 2000/2002/2007) in the late 1990s, the technological literacy focus of T&E education has withstood almost two decades of debate. Many states have incorporated the standards and benchmarks in their curriculum frameworks, and the national Praxis II exams for technology education certification adopted the standards for content test questions. One area of future debate is, "Should the standards be revised or dropped for something new?" If there is a strong push to drop technological literacy and focus solely on engineering, then a change may be inevitable. It is interesting to note, though, that the word engineering is used 160 times in *Standards for Technological Literacy*, so one could surmise that engineering content is already addressed.

Additionally, if we drop technology from our field to become solely engineering education, do we become a Career and Technical Education (CTE) track or Advanced Placement Honors pre-engineering program specifically for the select few students who want to become engineers? This could cause the collapse of programs in public middle and high schools so that they be-

come a one-teacher program offered as a CTE program of study. Some school systems currently have pre-engineering programs like this, offered as a CTE cluster that is funded through Perkins dollars; however, these programs employ a selective application process and fail to provide opportunities for every student to enhance his or her technological literacy as provided by current middle and high school T&E courses.

Finally, there is the impact of the shrinking undergraduate teacher preparation programs. The number of programs has dropped from 68 in 2003 to 43 in 2015. The number of graduates has plummeted from 716 in 2003 to 245 in 2015 (Love, Love, Love, 2016). At a time when states are opening up more courses to technology education certification requirements, school districts are finding it increasingly difficult to hire certified T&E teachers to fill these positions. This is leading to the hiring of more out-of-field transfer teachers and engineers with varying requirements of additional coursework to obtain certification. This pathway bypasses state and national Council for the Accreditation of Teacher Preparation (CAEP) accredited teacher preparation programs that emphasize the generalist technological pedagogical practices critical for proficiently teaching T&E concepts. Many of these accredited T&E teacher preparation programs have made a conscientious effort to align their curriculum with the Designed World section of *Standards for Technological Literacy* (Litowitz, 2014).

If technology is removed from our field, are we prepared to adequately teach engineering concepts? Fantz and Katsioloudis (2011) identified that, although many programs changed their names to reflect T&E education, most were not preparing pre-service teachers with sufficient engineering knowledge to teach this content. The key for the survival of T&E education lies not in shifting our focus away from technological literacy, but in renewing support for the remaining T&E teacher education programs across the United States.

Conclusion

As T&E education seeks to survive a shortage of teachers and funding, among other factors, it must proceed with caution. The field should remain true to its hands-on, design-based roots but must also provide rigorous instruction that applies STEM skills and situates it as a valuable stakeholder among the core content areas. Dropping the T would not solve the public's misconception of what we teach, rather the authors believe another name change to the field would increase this misunderstanding. Adding engineering to our name has helped provide some clarification in what we do and remedies the common misconception that technology education is instructional technology. Technological literacy is the right focus for the future because it provides an opportunity for T&E education to reach more students, not just those interested in specific vocational skills or becoming profes-

sional engineers. The inclusive approach has served the field well over many years. There is room for manufacturing programs in the Midwest, gaming development courses in the South, and traditional courses in rural areas. Making a change to a purist engineering education or returning to an industrial arts focus will not adequately serve our field and will increase pressure to close down secondary and higher education programs nationwide. The inclusive technological literacy approach that serves all students continues to be the best direction for our field at this time.

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engineering education: a clear decision

The profession has reached a tipping point with respect to the need for recasting itself as Engineering Education and the impetus for returning to its original focus and alignment to engineering at the post-secondary level.

The core subjects in P-12 education have a common key characteristic that makes them stable over time. That characteristic is a steady content. For example, in the sciences, the basics of biology remain the same—the cell is the basic building block around which organisms are defined, characterized, structured, etc. Similarly, the basics of physics and chemistry are relatively constant, with incremental increases in understanding adding to those basics when impacted by new discoveries over time. The same case can be made for mathematics, whose basic content has been unchanged for centuries and only expanded upon as old theories make way for new. In the same sense, the content of language arts has remained

relatively constant over time. As a result, these subjects have maintained their relevancy in P-12 schooling as core knowledge all students should acquire.

There are, however, some P-12 subjects whose content is far more fluid and that regularly change due to the very nature of that content. This is the case for what today is called Technology and Engineering Education (TEE). Unlike the core subjects, the content of TEE changes in concert with advances in global economies and their associated technologies and practices.

by
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This is evident in the periodic name changes that have occurred since Manual Training was included as a P-12 subject in the late 1800s. This focus on manual training did not last long and, by the turn of the century, soon fell out of favor in the context of newer education models and an ever-changing economy. Manual training evolved into Manual Arts, soon thereafter into Industrial Arts, and so on throughout the 1900s. The recurrence of these transitions has become a hallmark of a field attempting to be responsive to constant and rapid technological advances. And, like each advance, the transition made by the field soon became obsolete. This scenario is repeated throughout the history of the profession, as in the most recent case for Industrial Arts Education in a post-industrial era changing to Technology Education and, subsequently, Technology and Engineering Education in the context of STEM education. Again, this pattern of continual name change reflects a field repeatedly attempting to keep pace with evolving content associated with rapid technological advances. Moreover, the uncertainty of such advances makes it difficult to predict changes in associated practices to be taught. This is in stark contrast to core subjects. These subjects remain relevant in P-12 schooling over time because their content is relatively stable, and because of a clear recognition for the contributions they make toward maintaining the vitality of our democratic society.

The latest change in our professional identity occurred in 2010 when we renamed ourselves "Technology and Engineering Education." As in the past, the impetus for the name change was driven by a force external to education, in this case the STEM Education Reform movement that arose in response to national workforce issues. Within this acronym, our field positioned itself to be both the "T" and the "E," and in so doing, has laid the groundwork for a potential paradigm shift. What is most significant to note as a result of this name change is recognition within the field of the strong parallels in content and practice found between the engineering and technology education disciplines. As a result, throughout the nation and at all levels, technology education programs have been incorporating engineering education content at an ever-increasing pace. This is not only evident in the national curricula, but in the extent to which programs across the country have renamed their courses to include engineering in their titles and focusing more on teaching the content of engineering education.

There is no question that our profession has aligned itself with engineering education—an alignment that is providing us with a pathway to firmly establish Engineering Education as a core P-12 subject. And like the other core subjects, one with a recognized content and practice that has remained resilient and constant over time. What remains is to have the profession be bold enough to take the final step in recasting itself as simply the International Engineering Education Association (IEEA) responsible for delivering general education literacy on engineering

content and design practices at the P-12 level. In truth this is the exact role we strayed from in the late 1800s by not remaining aligned at the secondary level with the rise of engineering in higher education. Recasting now, however, realigns our pathway and will result in an independent core P-12 subject whose content and practice has recognizable value and that has been both constant and resilient over time.

The dialogue on transitioning to engineering education has already begun through publications in our field (Strimel & Grubbs, 2016) and will continue through public debate beginning at our 2017 national conference. Regardless of venue, there is ample evidence to support the rationale for transitioning out of our current paradigm and recasting ourselves as engineering education. This evidence can be organized around five main issues currently plaguing the Technology and Engineering structure, and which are remediated under Engineering Education. Specifically, P-12 Engineering Education provides:

1. A subject area distinct and independent from all others.
2. Clarity of content and practice to be taught.
3. Alignment with goals/outcomes of core subjects.
4. Scaffolding for grade-appropriate tool knowledge and technique.
5. A professional pathway not currently afforded in P-12.

Evidence Supporting the Transition to Engineering Education

Distinct and Independent Subject Area

The challenge in communicating the role of technology education in P-12 education has long plagued the profession. Perhaps the most evident challenge is being misperceived as a subject centered on electronic devices, such as the confusion with "computers" and "educational technology" (Dugger & Naik, 2001). Or, perhaps being cast as solely "shop" class or a nonacademic subject due to its historical roots in industrial arts. Likewise, technology education is often convoluted with career or technical education (Wicklein, 2006), which hinders its ability to reach all students. Conversely, many in our field have recognized that recasting ourselves as engineering education "separates us [technology education] from educational technology" and clarifies our subject area because "people understand what engineering is" (Starkweather, 2008, p. 28). For example, in the following definition, what term immediately comes to mind?

"_____ is the application of mathematics, empirical evidence and scientific, economic, social, and practical knowledge in order to invent, innovate, design, build, maintain, research, and improve structures, machines, tools, systems, components, materials, and processes."

Those in our profession are likely to say technology education is the term that comes to mind. In truth, the above definition is one



commonly employed to describe the field of engineering (ICJE, 2016, para. 3). Yet, though a definition of engineering, it clearly encompasses the intent of the TEE school subject.

Based on results from a 2008 survey, Starkweather reported a majority agreement among technology education professionals that changing the name of the discipline to include engineering would have a positive impact on the field. In turn, recommendations were made to recast the subject as Engineering Technology Education (ETE) to better align with the structures of higher education. However, the discipline was instead renamed Technology and Engineering Education (TEE) in 2010 and to date continues to struggle in communicating itself as a distinct and independent school subject. This struggle is aggravated by the incorporation of engineering content and practices in the new national standards for science education. Since the release of *Next Generation Science Standards (NGSS)* in 2013, science education gained both attention and support as a key subject area for implementing P-12 engineering education. In turn, the distinction between science education and technology education has become increasingly vague, adding to the ambiguity of technology education as a P-12 school subject with a unique content and practice.

Although science education has received attention for including engineering within its national standards, *NGSS* states it is not intent on establishing a full scope of coursework in engineering. The inclusion of engineering practices in *NGSS* was to provide a mechanism for teaching science concepts and developing practices beneficial to all students for the 21st century. Given the current position of science education, it is therefore still neces-

sary at the P-12 level to have engineering education as a stand-alone program providing learning progressions for engineering content and practices within and across all grade bands (Samuels & Seymour, 2015). As Pinelli and Haynie (2010) state, "it is imperative that engineering be included in the K-12 school curriculum, both as a discipline and as a source of enrichment and context for teaching other subjects" (p. 65).

The argument for a distinct and independent engineering education program is gaining traction among those who recognize engineering as both a discipline and as a pedagogical practice that helps students develop valuable skills while connecting them with potential pathways for postsecondary study (Cogger & Miley, 2013). Capitalizing on this recognition, a shift

in focus from technology education to P-12 engineering education promotes greater public understanding, thereby increasing its support and acceptance as a requisite subject alongside the other core disciplines.

Clarity of Content and Practice to be Taught

Consider for a moment just what makes TEE an irreplaceable and valuable component of a student's general education. One may look to pedagogies supporting experiential or situational learning facilitated through minds-on/hands-on design challenges as characteristics defining this school subject. However, increasingly teachers of other school subjects are providing instruction using hands-on problem- and inquiry-based practices within the guise of engineering practices. For example, *NGSS* specifically employs engineering practices as a mechanism for teaching science concepts. Moreover, schools, particularly within their media centers, are beginning to establish makerspaces where students can work with their hands to produce or "make" products using some of the latest technological tools and software. Consequently, such pedagogical approaches are no longer unique to, nor distinctive of, TEE. In this context, TEE is increasingly challenged to clearly establish itself as a stable content and set of practices all students should know and be able to demonstrate as part of secondary schooling. The logical direction appears evident—recast as engineering education or become irrelevant within P-12 education.

As stated in the 2010 *Standards for K-12 Engineering Education?* report, establishment of engineering content for P-12 can provide the identity for a necessary and separate school subject—one

Table 1. Nine Big Ideas for Engineering Standards (Practice)

Engineering Education Dimensions	Big Ideas
Engineering Knowledge	Engineering design is an approach to solving problems or achieving goals.
	Technology is a fundamental attribute of human culture.
	Science and engineering differ in terms of goals, processes, and products.
Engineering Skills	Designing under constraint.
	Using tools and materials.
	Mathematical reasoning.
Engineering Habits of Mind	Systems thinking.
	Desire to encourage and support effective teamwork.
	Concern for the societal and environmental impacts of technology.

Note: National Research Council (NRC). (2009, p. 131).

that can stand alongside the already well-established core subjects, such as mathematics and science. A shift to engineering enables the profession to focus on delivering stable engineering content that aligns with postsecondary studies and fosters designerly ways of knowing and engineering habits of mind. In doing so, it provides crucial opportunities for students to use tools, materials, and software to design, make, tinker, troubleshoot, and eventually create effective solutions to meet human needs based on an engineering-design process that inherently requires higher-order cognitive abilities (Wells, 2016). Action is necessary to advance the TEE curriculum and instruction to address an engineering education focus. Work on organizing content and practices has already begun and is available to guide such transformation towards engineering education.

As a first step in clarifying content and practices for P-12 Engineering, the profession can build upon current practice and con-

tent structures provided by the Nine Big Ideas for Engineering Standards (Table 1) and the Core Engineering Concepts, Skills and Dispositions (Table 2) as identified by the National Research Council (2010, p. 35-36). In so doing, P-12 Engineering Education would be aligning with postsecondary engineering education as a potential career pathway for those who are inclined to enter a related field of study. Tables 1 and 2 reflect well-established structures for current engineering practices and content respectively that provide the vertical alignment necessary across all grade bands that better articulate potential pathways to postsecondary STEM education.

Concurrent with the acquisition of engineering content is development of engineering practices requisite for promoting designerly ways of knowing and engineering habits of mind. Close alignment with the practice of engineering design in P-12 engineering education serves to direct students away from a

Table 2. Taxonomy of Engineering Fields: Engineering Discipline and Subfields (Content)

Aerospace Engineering	Civil and Environmental Engineering	Electrical and Computer Engineering	Mechanical Engineering
Aeronautical Vehicles Space Vehicles Systems Engineering and Multidisciplinary Design Optimization Aerodynamics and Fluid Mechanics Astrodynamics Structures and Materials Propulsion and Power Navigation, Guidance, Control, and Dynamics Multi-Vehicle Systems and Air Traffic Control	Civil Engineering Construction Engineering/ Management Environmental Engineering Geotechnical Engineering Structural Engineering	Biomedical Computer Engineering Controls and Control Theory Electrical and Electronics Electromagnetics and Photonics Electronic Devices and Semiconductor Manufacturing Nanotechnology Fabrication Power and Energy Signal Processing Systems and Communications VLSI and Circuits: Embedded/ Hardware Systems	Acoustics, Dynamics, and Controls Applied Mechanics Biomechanical Engineering Computer-Aided Engineering and Design Electro-Mechanical Systems Energy Systems Heat Transfer, Combustion Manufacturing Ocean Engineering Tribology

Note: For the complete list, please visit http://sites.nationalacademies.org/PGA/Resdoc/PGA_044522

routinized approach to designing and toward a more rigorous engineering practice requiring student use of appropriate mathematics and science concepts in conjunction with technological tools for optimizing solution designs. This focus overcomes the current challenges TEE faces with implementing an analytical engineering-design approach focused on optimization (Merrill, Custer, Daugherty, Westrick, & Zeng 2009).

Such approaches provide a solid starting point for the subject to become a clear and distinct field of engineering education content and practices at the P-12 level. While *Standards for Technological Literacy* (2000/2002/2007) includes an emphasis on engineering, engineering education offers more exclusive and engaging content and practices in areas such as electrical circuits, robotics and automation, design and modeling, statics, dynamics, material properties, project management, executive functioning abilities, proper use of tools and materials, and concepts of each engineering discipline. The specificity of this content and practice presents a stable P-12 Engineering Education framework that avoids the fragmented teaching of engineering concepts and practices currently found in TEE curricula. Specifically, P-12 Engineering Education provides explicit content, concepts, and processes not presently taught, developed, or intentionally assessed as part of developing technological literacy.

Alignment With Goals/Outcomes of Core Subjects

Though the philosophy of TEE has always been grounded in general education, the field has often found itself positioned under the umbrella of vocational or technical education. In most states, TEE is therefore not considered a core subject for all students—rather, it is relegated to being an elective, or vocational, pathway. Recast as P-12 Engineering Education, the subject area is better positioned to achieve the goals of general literacy and development of targeted cognitive abilities that other core subjects strive to achieve. In aligning with core subject learning outcomes and goals, all students achieve similar benefit from engaging in the content and experiences within P-12 Engineering Education. Furthermore, as is currently the case with other core areas, a recast P-12 Engineering Education program aligns with higher education and provides a distinct educational pathway with valuable content and practice that will remain consistent and resilient over time.

Scaffolding for Grade-Appropriate Tool Knowledge and Technique

The national Technology and Engineering Literacy (TEL) assessment results indicate that grade eight students have few valuable opportunities to practice tinkering, designing, making, and testing solutions during school (Change the Equation, 2016). These opportunities have traditionally been core characteristics of tech-

nology education programs, which have conventionally provided authentic learning environments for students to explore and understand the proper use of industry-standard tools, materials, and software through project and problem-based instruction. Currently though, these features are fading from high school TEE programs forced to transition toward use of low-cost, low-technical materials such as Popsicle sticks, tape, and hot glue as their main sources for production or making (Grubbs, 2014). While still acknowledging the economic constraints many high school programs face, materials of this level may only be appropriate for exploratory programs at the elementary and middle school levels. However, this lack of authenticity at the higher grades leaves many students with an absence of experience in material testing, analysis, and processing that would provide them the abilities to conduct experiments and perform predictive analysis when developing real solution designs. A shift to Engineering Education necessitates use of industry-quality software, tools, and equipment to properly engage students in an authentic engineering design process.

In the ideal situation, P-12 Engineering Education provides the scaffolding for grade-appropriate tool knowledge and technique that is both engaging and valuable for students. Students in the early grades will begin experimenting with tools and materials through more structured engineering design problems while building confidence in their design and creative abilities. As students construct their knowledge of technologies or tools, science, mathematics, and design across the grade levels, engineering education engages them in more authentic, structured challenges that increasingly require their knowledge of more complex and complicated technologies that are obligatory for engineering design. Consequently, Engineering Education revitalizes the scaffolding of tool knowledge and technique as it better imposes the need to use these technologies in authentic situations.

In the context of this proposal to transition to Engineering Education, consideration must be given to the appropriate funding structures to support the change. Given the ideal scaffolding for grade-appropriate tool knowledge and technique, a concern may be the cost of such resources. However, P-12 Engineering Education positions technology education to take advantage of funding opportunities for establishing makerspaces or for implementing resource-rich engineering programs such as Project Lead the Way. In addition, an Engineering Education focus necessitates the use of design, data visualization, and application development software, which continue to be offered free of charge to teachers and students. Therefore, the content and practices of P-12 Engineering Education will ensure that the safe and grade-appropriate tool knowledge and techniques necessary to design and “make” remains a critical and engaging feature of every student’s educational experience.

A Professional Pathway Not Currently Afforded in P-12

The argument has been made that one objective of P-12 Engineering Education programs should be to encourage more students to consider engineering and related career pathways to address the challenges facing U.S. innovation (NRC, 2009). In addition, there are several identified factors that impact a high school student's decision to pursue an engineering degree, such as lack of guidance, lack of knowledge about engineering, and low aptitude (Samuels & Seymour, 2015). These and many other drawbacks are addressed through a coherent and consistent general education approach to Engineering Education. In addition, P-12 Engineering Education will help improve retention in undergraduate engineering programs, as many students leave engineering pathways over lackluster exposure to the type of work performed by engineers (Hirsch, Carpinelli, Kimmel, Rockland, & Bloom, 2007) or because of a lack of sufficient preparation for the rigors of mathematics and science at the postsecondary level (Fleming, Engerman, & Williams, 2006). Exposure to Engineering Education at P-12 levels affords students the opportunity to experience and understand engineering and engineering technology as a means of gauging its potential as a career pathway. Even a decision not to pursue an engineering-related career will help students achieve their postsecondary goals sooner while obtaining knowledge and skills from their pre-college engineering studies that will be helpful in any career pathway.

A Clear Decision

The earlier forms of TEE in the late 1800s were closely aligned with higher education and originally intended as precursors to postsecondary studies of manual training, which transitioned to engineering as it became established as a core field of study. In the years since, TEE has strayed from this path, with subject content and practices becoming increasingly unstable and devalued over time. This is poignantly reflected in findings by Litowitz (2014) depicting a steady decline of TEE programs since the 1970s. These and other data demonstrate the profession has reached a tipping point with respect to the need for recasting itself as Engineering Education and the impetus for returning to its original focus and alignment to engineering at the postsecondary level. The multitude of evidence clearly indicates the need for transitioning to P-12 Engineering Education. Equally clear is that, should we decide not to transition or should we hesitate further, others are poised to claim the "E" regardless of their disciplinary history and experience.

To illustrate this point, one can look at the first national assessment of technology and engineering literacy (2016) results. These results indicated that only 43% of eighth graders assessed in 2014 were on track to become proficient in systematically using

engineering information and technology to efficiently develop the best possible solutions to authentic problems. While these results highlight a need for more engineering/technology learning opportunities, the Change the Equation (2016) report refers to science classrooms rather than technology classrooms as a means to address this need due to science education's ability to reach all students. Clearly it is time to make a decision. Drawing from the evidence presented in this paper, there is only one viable pathway for the field—recast itself as P-12 Engineering Education. Not doing so signals a profession that is resigned to becoming irrelevant and a subject destined to lose its presence in P-12 schooling.

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Figure 4. Renewable energy is going to be a disruptive technology.

twenty-first century skills

Student learning outcomes, beyond the traditional, need to be crafted for the 21st century learner.

Introduction

Except for the Great Depression, the United States' economy boomed during the first three-quarters of the 20th Century. America developed into an industrial and technological giant. Factories covered the landscape. Families joined the middle class in droves. Leading into the 1970s, this was the kind of economy that fueled a higher standard of living for the new middle class. It was a manufacturing economy that was reflected in all parts of society. Even the process of education was modeled on the factory (Apple, 1979). Classes changed on the sound of a bell. Each student tended to his or her own studies. The teacher was the center of focus. These were certainly reflections of a production economy that has survived into the 21st Century. But since the 1970s, the economy has been shifting (Stone, Trisi, Sherman, & DeBot, 2015). In the face of an inadequate response to the changing economy, the wealthy are becoming wealthier, the middle class is experiencing a lower standard of living

relative to most of the 20th Century, and poverty is still a concern (Dabla-Norris, Kochhar, Suphaphiphat, Ricka, & Tsounta, 2015). In part, these effects are policy-related, but they are also technology-related.

The Shifting Economy

In the early days of personal computing, users had to write programs to get the computers to perform as intended. For the average employee, word processing and accounting were tedious tasks because of the programming required. Eventually, computer programmers began to write operating systems and software for personal computers that allowed anyone to use them. The user no longer had to program a word processor, but could now simply use a purchased program to write a letter. This capability popularized personal computers. Then, as more people purchased personal

by
Vincent W.
Childress

computers, they became so affordable that billions more people around the world were able to purchase them. These billions were located in the Soviet Union, which fell, and India and China, which began removing obstacles to trade. Finally came the rise of the internet. The ability of people to communicate nationally from computer to computer was one step in this process, but when dot com companies wired the globe with broadband networking technology, the global economy and the nature of work changed forever (Friedman, 2005). Over this phase of technological change, many governments around the world reduced bureaucracy and entered into trade agreements that removed many barriers to global trade, such as tariffs and restrictions on expatriate business starts.

Once these technical and policy components were in place, companies found that they could communicate and process data in real time around the world. With computer software and the proliferation of personal computers, the internet, broadband access, and free trade, companies were able to transition from traditional top-down organizations to horizontally organized efforts that became more innovative and able to react to change more quickly. They have been able to outsource labor-intensive processes to lower-wage, lower-cost locations offshore, and they have even opened their own operations offshore (Friedman, 2005). Simultaneously, automation for financial and communication processes, transportation, agriculture, and manufacturing technology has significantly improved efficiency for operations that have remained in the U.S.

Because of these changes, the days in which a young person could drop out of high school, get a factory job, and lead a modest but secure lifestyle are gone. In the past, someone with a high school diploma could get a manufacturing job and live a middle class existence; not anymore. College graduates used to be able to hold a management job for life and retire on the company's pension plan; not anymore. The circumstances described above have created a dynamic and highly competitive business environment around the world and have changed the global economy and the nature of work.

However, this economic change has happened so rapidly that people have not been able to adapt to it, and the income inequality that began to evolve as productivity declined in the 1970s is now becoming greater in the global economy.

There are profound implications for workforce education. It is not enough that students and displaced workers pass tests and keep up with technology. The 21st century worker will be (and is) communicating with diverse customers and diverse coworkers from around the world or will be assisting those who do. With increases in immigration to the United States, their immediate coworkers will have diverse backgrounds. They will experience

rapid deployment of innovative ideas, and they must be able to adapt to those innovations. Lifelong learning will be second nature to them if they are to succeed. In the face of this change, 21st century workers must become problem-solvers who can both collaborate with people from diverse cultures and at the same time think critically for themselves. They must be able to think creatively and communicate effectively to participate in the development of innovations that will drive the economy in the global market.

Wealth and Poverty

The short-term result of this economic shift thus far in the 21st century is that the top 10 percent of Americans, who had already accumulated wealth, are growing more wealthy, while thousands of Americans have lost their higher-paying production jobs and have taken lower-paying ones that are not supporting their families at a level to which they had become accustomed. And for those who were already working low-skill, low-wage jobs, they are seeing very little or no wage growth whatsoever (Stone et al., 2015).

The inability of displaced workers to adapt is creating a widening gap in income and wealth between the lower 90 percent of American families and the upper 10 percent of families. For the richest 1 percent of Americans, income grew 200% since 1979. It grew 67 percent for the next richest 19 percent, 48 percent for the middle 60 percent, and 40 percent for the lowest 20 percent of Americans, the poorest. Most of that growth occurred in the 2000s (Stone et al., 2015). The same thing is true for wealth accumulation. The top 10 percent of wealthiest families in the United States hold 75 percent of the nation's wealth (Stone et. al.).

While minority wages have grown some recently, the wealth gap between whites and minorities has grown wider. As of 2013, median net worth for white families was \$141,900, for black families, \$11,000, and for Hispanic families, \$13,700 (Kochhar & Fry, 2014). A person's sex matters too. Women in the United States only make 79.9% of what men earn (Proctor, Semega, & Kollar, 2016). Generally, minority women with the same education make significantly less than white women. This pay gap impacts families. The percentage of mothers earning one-fourth of the family's income or greater increased to 63 percent as of 2012, and for 40 percent of mothers with school-age children, the gender pay gap is a cause of reduced nutrition, less healthcare, and fewer opportunities to experience activities that enrich learning (American Association of University Women, 2016).

It is important to keep in mind that the United States is emerging from economic recession with a low rate of growth. However, for 2015, the U.S. Census Bureau reports an overall poverty rate of 13.5% (or approximately 43.1M people), down 1.3% from 2014. Females (heads of household), blacks, Hispanics, and children

have the highest poverty rates. However, all four of those groups experienced the largest reductions in poverty rates from 2014 to 2015 (Proctor, Semega, & Kollar, 2016).

Standard of Living

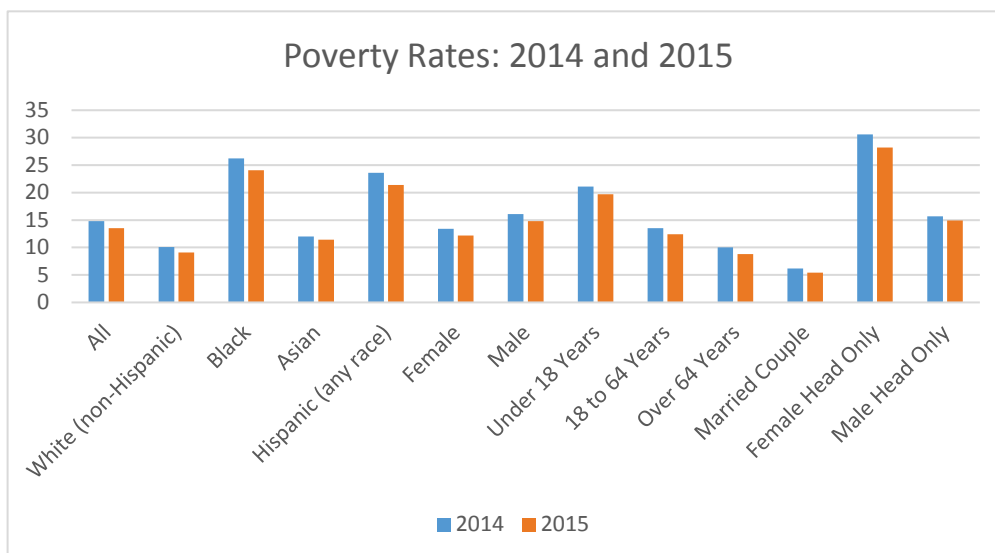
The Economic Policy Institute is a labor-union-supported think tank focused on policy that affects lower and moderate income workers. It asserts that policies are to blame for income and wealth inequality. It claims that for the past three decades, the economy was strong enough to support wage growth for low and moderate income workers, but most of the real gain went to the wealthiest one percent of Americans. The Institute estimates that for the middle three-fifths of Americans, a median income of \$76,443 would have been \$94,310 in 2007 had there not been growth in income inequality. The Institute also estimates that between 1948 and 1973, productivity increased by 96.7% and hourly wages increased 91.3%. But, between 1973 and 2013, productivity increased 74.4% and hourly wages only increased 9.2% (Mishel, Gould, & Bivens, 2015). A Pew Research Center estimate clearly illustrates the problem with the standard of living in the new economy. Between 1964 and 2014, when adjusted for purchasing power, the median wage for private sector production and nonmanagement workers (excluding farm workers) grew by only \$1.49 (Desilver, 2014).

Wealthy families can buy the goods and services that they need. Poor families, not as well. Wealthy families typically have a network of friends with power and influence on whom they can call for opportunities. Poor families, not typically. Wealthy families, by and large, have been well educated for generations. Poor families have not. This is the inequality of income, and this is the inequality of opportunity (Dabla-Norris et al., 2015). Working families, the

Table 1. U.S. Poverty Rates by Demographics (Proctor, Semega, & Kollar, 2016)

Demographic	Group	Poverty Rate (%)		Change (%)
		2014	2015	
All	All	14.8	13.5	-1.3
Race	White (non-Hispanic)	10.1	9.1	-1.0
	Black	26.2	24.1	-2.1
	Asian	12.0	11.4	-0.6
	Hispanic (any race)	23.6	21.4	-2.2
Gender	Female	13.4	12.2	-1.2
	Male	16.1	14.8	-1.3
Age	Under 18 Years	21.1	19.7	-1.4
	18 to 64 Years	13.5	12.4	-1.1
	Over 64 Years	10.0	8.8	-1.2
Marital Status	Married Couple	6.2	5.4	-0.8
	Female Head Only	30.6	28.2	-2.4
	Male Head Only	15.7	14.9	-0.6

working poor, and the poverty stricken have more worries than do the wealthy, and this can create disadvantages. Parents may need to work two jobs, transportation may be unreliable or inefficient, communication technology may be unavailable, and even housing may become a concern. A family might have Medicaid, but cannot visit a doctor because area doctors stopped accepting Medicaid patients. As a community falls into economic distress, grocery stores move away, creating "food deserts." Depending on whether or not a community has effectively diversified its economy, the community itself may be poverty stricken. Whether urban or small town, old plants from the manufacturing heyday may litter the landscape. In the countryside, fields that were once sown with crops lay dormant. The lack of meaningful employment creates crime, and local governments are not able to provide services or supplement funding for schools. In turn, high-skill, high-wage employers are reluctant to locate there.



Twenty-First Century Technology

It is important to remember that the average citizen of the United States is better off today than he or she would have been at the turn of the last century. While there

Figure 1. U.S. poverty rates by demographics (Proctor, Semega, & Kollar, 2016).



Figure 2. Mobile internet will sweep the world within the next 10 years.

may have been limited growth in buying power more recently, the standard of living truly is better now than it was then. In 1900, there were relatively few consumer goods to buy. People had to make things for themselves, but now the variety of goods is nearly overwhelming. Then, there was limited credit for buying land and a home, but now credit is more widely available. As factories shifted from water to coal for power, air and water quality declined, but now factories are cleaner. Average life expectancy in 1900 was 49.24 years (Arias, 2015), and as of 2013, average life expectancy is 78.8 years (Xu, Murphy, Kochanek, & Bastian, 2016). Then, like now, key technological innovations caused the economy and the nature of work to change.

Technology Diffusion

The extent to which a technological innovation is adopted throughout society is known as technology diffusion, and widely diffused innovations tend to have a larger economic impact. Technology diffusion can proceed relatively rapidly or relatively slowly. For example, the steam engine had various uses. It quickly spread to power locomotives, ships, automobiles, farm equipment, and factories. However, the electric motor had limited

applications at first because most factories were rigged with mechanisms that transmitted steam power. Gradually, as factory after factory upgraded, the electric motor became one of the most fundamentally important inventions in economic history. The electric motor made it possible for manufacturers to open up more production lines and more factories, employing more people (Manyika, Chui, Bughin, Dobbs, Bisson, & Marrs, 2013). As described so well by Friedman (2005), the internet's diffusion followed a similar process.

Three of the wealthiest nations on earth are the United States, Germany, and Japan. They also spend more on research and development than any other country. Innovations from these three countries are diffused (as ideas) to other countries that, in turn, profit from production related to the technology. Sometimes the ideas are pirated and sometimes licensed, but this diffusion process demonstrates that innovation drives both wealth and productivity (Eaton, 2016).

Disruptive Technologies and Emerging Job Markets

Innovative computer technology enabled the latter half of the economic shift discussed thus far, and technological innovations will continue to drive the new economy. These drivers are transforming America's emerging job markets—and the world's. Manyika et al. (2013) refer to widely diffused technologies as “disruptive” if they have the potential to change the economy. Disruptive technologies cause the displacement of workers in fields that are affected by the technological innovation and its diffusion. For example, the ability of computers to learn and handle large amounts of data is making it possible to automate processes related to knowledge work, clerical work, and transactions. Computing technology is now able to interpret variable voice commands, organize data, and manipulate the data to complete processing with much less human intervention compared to the recent past. The implication is that, within the next 10 years, any sort of data-processing staff, managers, accountants, clerical staff, and transaction clerks could become obsolete or used to take care of only the most complex operations (Manyika et al.) The extent to which this would shift the workforce would far exceed the extent to which clerks have been replaced by ATMs and self-checkout. However, the automation is estimated to save companies, governments, and consumers billions of dollars (Manyika et al.).

Mobile internet is predicted to be another disruptive technology. With the assistance of satellite technology, cell phone coverage will expand to remote locations in developing countries, and the remaining 40 percent of the world's population will gain access. Mobile computing with advanced smartphones will benefit the poor, save governments money, and open up vast markets for commerce and trade. The potential for increases in employment extend less to those occupations concerned with the development and maintenance of the system, and more to the increase

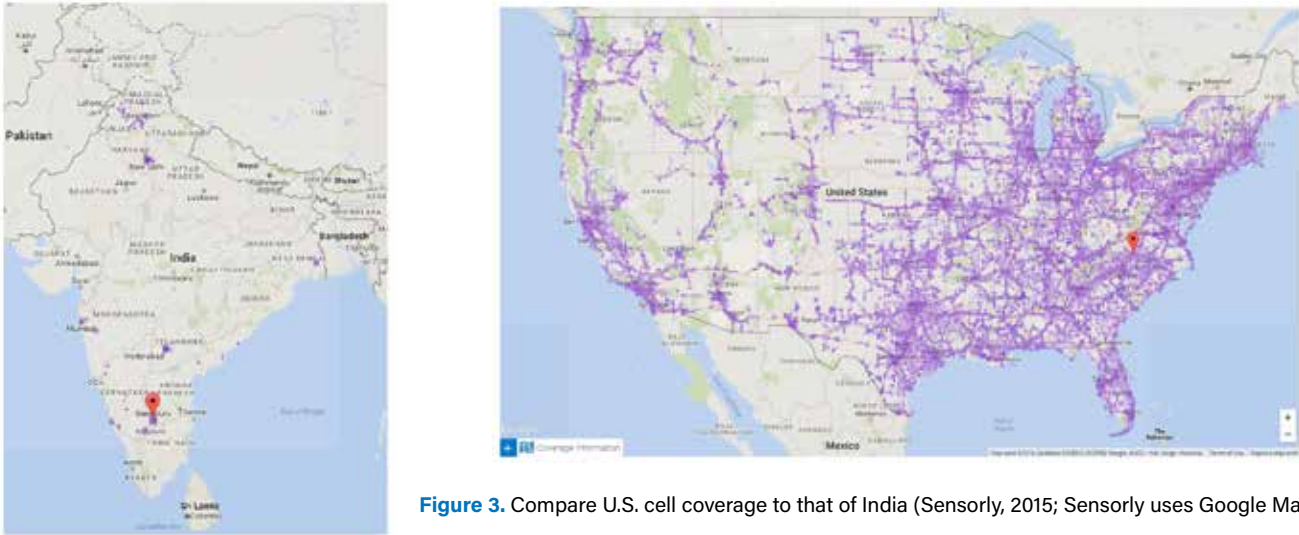


Figure 3. Compare U.S. cell coverage to that of India (Sensorly, 2015; Sensorly uses Google Maps).

in manufacturing of goods overseas, shipping and logistics, and management of commerce (Manyika et al., 2013).

Renewable energy is finally becoming a significant part of the economy. Wind and solar are becoming economically viable and more widely diffused. The cost of solar panels is going down, and efficiency is going up. Simultaneously, people are more concerned about greenhouse gasses from the burning of fossil fuels. Wind energy could follow suit. Depending on the price of fossil fuels into 2025, significant changes could result in the power-generation industry, affecting jobs with some shift from power plant operations to grid management and installation (Manyika, et al., 2013). In fact, Manyika, et al. (2013) have predicted that there will be 12 disruptive technologies as shown in Table 2 (next page).

Preparing for the Future

Over the last century, technology has changed drastically, innovation is increasing exponentially, but the implications for workforce education have not changed much at all. In the early 1900s, Dewey called for a shift from classical education to one of relevancy, in which each student would be prepared as a lifelong learner and problem solver; the only sure way to prepare for an uncertain future in the midst of the Industrial Revolution. At the start of the Cold War, there was a push for people to go into science and technology to solve the nation's defense and industrial problems. In the 1990s, the SCANS report called for the development of employee skills needed by all employers. And now in the 21st Century, leaders are calling for 21st century skills. Throughout that progression and now, the workforce and students have been urged to become career-ready.

Career and College Readiness

Student learning outcomes, beyond the traditional, need to be crafted for the 21st-century learner. It is essential that each

student develops a foundation of knowledge, but that is only the beginning. He or she must then have the opportunity to engage in learning that builds on that foundation. There must be enough time in the school day to allow students to actually move from simple application to creation of solutions to problems. There must be time for group projects with diverse students, set in motivating contexts that reflect real life, and these need to be both short-term and long-term opportunities for the student to transfer what was mastered to new situations. This engagement needs to include the development of speaking skills, reading comprehension, writing skills, presentation skills, mathematical reasoning, scientific reasoning, critical thinking, technology use, and career and college planning. Once on the job, each employee needs to stay abreast of changes in his or her occupation and related fields. Weekly readings and regular participation in professional development will help to make frequent workplace transitions go more smoothly.

More than anyone else, students whose families are at a financial disadvantage, as described in the section on income and wealth inequality, need to work hard at developing 21st century skills and should push for access to quality STEM programs and other college preparatory courses. They should join school and community clubs, such as the Technology Student Association, which will expose them to the world of technology through community service, internships, tours, competitions, and travel.

Classroom STEM

Have students create their own career-development plans. Start by taking one of the many career inventories available for free through your state or provincial employment agency. Have students research careers that are related to their interests. Show students how to access the *Occupational Outlook Handbook* at the Bureau of Labor Statistics' website. As an introduction to that site, click on "Fastest Growing" and "Most New Jobs."

Table 2. Technologies With the Potential to Disrupt the Economy.

Disruptive Technology	Occupations Declining	Occupations Needed - because of diffusion - to support the technology itself
Mobile Internet	Data processing and analysis, business clerks and managers, retail clerks and managers	Shipping, logistics, fulfillment
		IT technicians, application programmers, electronic engineers
Automated Knowledge Work	Data processing and analysis, business and government clerks and managers, retail clerks and managers	*See note
		IT technicians, computer programmers
The Internet of Things		Healthcare informatics
		IT technicians, electronic engineers
Cloud Technology	Data processing and analysis, business clerks and managers, some on-site information technology technicians	*See note
		IT technicians, computer programmers
Advanced Robotics	Manufacturing labor	*See note
		Automation and IT technicians, industrial, mechanical, electrical/electronic engineers
Autonomous Vehicles	Drivers, mechanics and fleet management (traditional)	Fleet management and maintenance (specialized)
		IT technicians
Genomics		Healthcare technicians and physicians
		Biologists, biotechnicians
Energy Storage		*See note
		Chemical, materials, mechanical, and electrical/electronic engineers
3D Printing	Subtractive machinists	*See note
		Automation and IT technicians, industrial engineers, mechanical engineers
Advanced Materials		*See note
		Materials and nano scientists and engineers
Oil & Gas Exploration		*See note
		Geologists, rig workers, welders/fitters
Renewable Energy	Power plant related	*See note
		Installers

* Because several of these disruptive technologies will tend to eliminate jobs instead of creating them, generally, these predicted shifts in the job market emphasize the need for people to pursue creative, innovative, and entrepreneurial occupations. These technologies will generally help owners of businesses become more efficient and consumers gain more access to goods and services at relative savings (Manyika, et al., 2013).

Students will quickly see that many of the fastest growing jobs are low-wage, but “software developers” and “IT professionals” are among the highest paid on the list. Be sure to point out that many of those careers listed under Fastest Growing and Most New Jobs are related to the disruptive technologies discussed in this article. Finally, as part of their planning, have students track requirements backward from job entry to college and from college to community college, from community college to high school, and, if appropriate, from high school to middle school.

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Ad Index

California University of Pennsylvania	Cover 4
Goodheart Willcox Publisher	43
Kelvin	42
North Carolina State University	43



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the supply and demand of technology and engineering teachers in the United States: who knows?

When considering the supply and demand of technology and engineering teachers, who knows where the profession stands? In 1997 Weston observed, "Enrollment in and graduation from technology teacher education programs are on a downward spiral" (p.6). Moyer (2009) stated, "...over the past two decades, the number of technology education teachers in the United States has decreased dramatically, and state supervisors reported that they expect more programs to close in the near future" (p.30). Moyer's 2009 study concluded that the profession was experiencing "a critical situation" (p. 30). Without recruiting new technology and engineering teachers and retaining current teachers and programs, the profession will continue to experience a "slow death" as Ritz suggested (1999, p. 9). Ultimately, "if we do not address the issues, soon we [the technology and engineering profession] will be going... going... gone" (Volk, 1997, p. 69).

It is not a normal practice for authors to start an article with so many quotes. However, this tactic is deemed necessary to reiterate a problem that the technology and engineering profession has experienced for at least the past 30 years. If we truly believe that all students should study technology and engineering, we need to ask ourselves: What are we doing to ensure there will be a sufficient number of technology and engineering teachers (and programs) to teach those students?

Even though the supply and demand of technology and engineering teachers could be considered one of the most significant challenges facing the profession, there appears to be very little accurate data on this topic. A review of the last 20 years of *The Technology Teacher* and *Technol-*

by
Johnny J.
Moyer, DTE

ogy and Engineering Teacher journals reveals that there were four studies with the purpose of determining the number of technology (and engineering) teachers in the United States: (Weston (1997), Newberry (2001), Ndahi and Ritz (2003), and Moye, (2009)). There were also four Status of Technology (and Engineering) in the United States studies performed in which the researchers also sought to determine the number of teachers in the U.S.: Meade and Dugger (2004); Dugger, (2007); Moye, Dugger, & Starkweather, (2012); Moye, Jones, & Dugger, (2015). The plan with all the studies conducted between 1997 and 2015 was to collect information about the number of technology and (engineering) teachers employed in the United States and then compare those numbers to previous studies.

Reports indicate that a large percentage of state supervisors responded to the 1997, 2001, 2003, and 2009 studies. In the 2004 study, Meade and Dugger reported, "20 states indicated that the number of technology education teachers was an approximation, which may imply that the same is true for other states" (p. 31). All 50 states reported in the 2009 study, but collecting the data painstakingly required many hours on the telephone to state supervisors in order to acquire the information. Several supervisors received multiple calls and email requests before they supplied the information. The researchers also made multiple telephone calls during the 2012 and 2015 Status studies. One would have to ask, did the supervisors provide accurate data or did they just provide information to get the researcher "off their backs?" Even with much effort to collect accurate data during the 2007, 2012, and 2015 studies, fewer and fewer supervisors responded with information for their states. In Dugger's 2007 Status of Technology Education in the United States study, 40 of the 50 state supervisors reported the number of teachers in their states. In the 2012 Status study, 34 of the 50 supervisors reported, and for the 2015 Status study, only 27 state supervisors provided the number of technology and engineering teachers in their states. Also, a review of the past ten years of *Journal of Technology Education*, found that there was no research focusing solely on the number of technology and engineering teachers, the number of vacancies, or program closures in the states. The point being made here is that researchers have faced difficulty acquiring accurate (if any) data when researching the number of technology (and engineering) teachers employed in the United States.

Recent research shows that technology and engineering professionals do not consider the supply and demand of technology and engineering teachers as a problem. In a modified Delphi study to determine Research Needs for Technology Education, Martin and Ritz (2012) solicited input from 17 technology teacher educators asking them what they felt were the most significant research needs. Of the seven research needs identified, none mentioned the need to study the supply and demand of technology (and engineering) teachers. The overall result of that study



Photo credit: Debra Shapiro.

appears that the technology (and engineering) teacher educators felt research needs should center on academic concerns versus a practical concern—the availability of teachers. Once the study concluded, Martin and Ritz identified what they felt was "a glaring omission" (2012, p. 40). Offering their opinion, they wrote, "as the number of educators in technology education continues to dwindle, our research attention needs to be directed to best practices in recruitment, specifically, identifying and implementing strategies to recruit new members into the teaching profession and retain those that are already serving as teachers" (Martin & Ritz, 2012, p. 40).

Purpose and Methods

The purpose of this study was to determine the supply and demand of technology and engineering teachers in the United States. Once gathered, the resulting data (that was available) was compared to previous studies to determine trends. Four methods were used to determine the supply; the researcher reviewed the 2010-11 through 2015-16 Technology & Engineering Teacher Education Directories. To determine the demand, the researcher reviewed two documents, the United States Department of Education Teacher Shortage Areas (TSA) Nationwide Listing 1990-1991 through 2015-2016 and the American Association of Employment in Education (AAEE) documents. The researcher also asked state technology and engineering program supervisors, state International Technology and Engineering Educators Association (ITEEA) Affiliate Representatives, and State Affiliate Presidents for the number of technology and engineering teachers employed and the number of vacant positions in their states.

Findings

Technology and Engineering Teacher Supply:

Researchers have used the Technology (& Engineering) Teacher Education Directories for the past 20 years to determine the number (or supply) of technology (and engineering) teacher graduates. The Council on Technology and Engineer-

Table 1. Number of Technology (and Engineering) Teacher Graduates 1995 through 2016.

Year	Number of TEE Graduates
1995-96	815
1996-97	635
1997-98	732
2001-02	672
2004-05	338
2005-06	315
2006-07	311
2007-08	258
2010-11	265
2011-12	338
2012-13	386
2013-14	294
2014-15	250
2015-16	206

ing Teacher Education provides “program listings for technology teacher education, engineering teacher education, industrial teacher education, and trade & industrial teacher education” (Rogers, 2015, p. i). In 1995-96, there were 815 technology teacher graduates. In 1996-97, 635 graduates; and in 1997-98, there were 732 (Ritz, 1999). In 2001-02, there were 672 new technology teachers (Ndahi & Ritz, 2003). In 2004-05, there were 338 new technology teachers, in 2005-06, 315; in 2006-07, 311, and in 2007-08, there were 258 new technology teachers (Moye, 2009).

50% of the colleges noted four or fewer graduates, with six schools having no graduates. This is an alarming trend that has plagued our discipline for decades (Rogers, 2015, p. ii). The Directories reveal that in 2010-11 there were 265 technology and engineering teacher graduates, in 2011-12, 338; 2012-13, 386; 2013-14, 294; 2014-15, 250; and in 2015-16 there were 206 graduates. Table 1 presents the number of technology (and engineering) graduates between 1995 and 2016.

One should be very concerned when reading the data contained in Table 1, but when that same data is presented in a chart—graphically illustrating the decline—it is even more disturbing. Figure 1 identifies the number of technology (and engineering) teachers produced from 1995 through 2016.

Technology and Engineering Teacher Demand

The United States Department of Education (USDOE) *Teacher Shortage Area (TSA) Nationwide List* does not define what constitutes a “teacher shortage area” but only if there is or isn’t “an inadequate supply of elementary or secondary school teachers” (USDOE, 2015, p. 3). The TSA document also states that it is a “reference document to notify the nation where States and schools are looking to potentially hire academic administrators, licensed teachers, and other educators and school faculty in specific disciplines/subject areas, grade levels, and/or geographic regions” (USDOE, 2015, p. 2). In 2008, the TSA list “reported that only 24 states indicated a shortage of technology education teachers” (Moye, 2009, p. 30).

The researcher reviewed the TSA document for the 2010-11 through 2015-16 years. Each year the 50 states were to provide a report to the USDOE. Therefore, there are 50 opportunities to

identify shortage or no shortage in each of those years. During those six years, states provided 300 reports. Out of 300 possible incidences states reported a shortage of technology/ design and technology education teachers 58 times (or 19% of the time). Table 2 (next page) identifies when states reported technology/ design and technology teacher shortages from 2010 through 2016. The “Y” indicates a shortage whereas the “-” indicates no shortage reported. Only the states that reported any shortages during 2010 through 2016 are included in Table 2.

Continuing the previously conducted research, six Directories were reviewed (Rogers, 2010, 2011, 2012, 2013, 2014, & 2015). In the most recent directory (2015), Rogers summed up a problem facing the technology and engineering profession (incidentally the focus of this study). He wrote:

Unfortunately the number of teacher education institutions along with the number of technology and engineering education graduates continues to decline. For the academic year data presented in this 54th edition, three institutions accounted for 36% of the baccalaureate graduates. Over

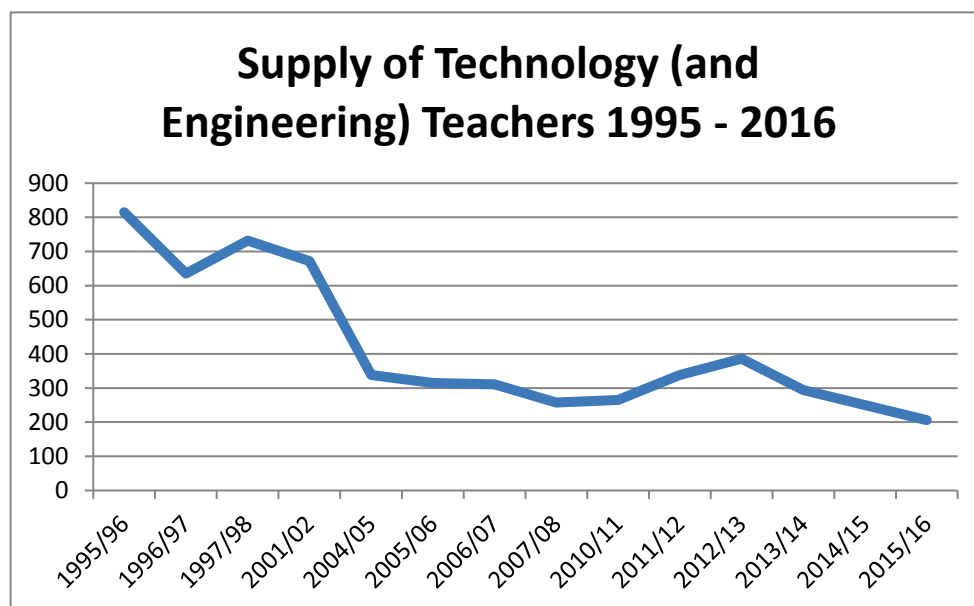


Figure 1. The Supply of Technology (and Engineering) Teachers in the U.S. 1995–2016.

The American Association for Employment in Education (AAEE) conducts educator supply and demand studies annually. Between 2003 and 2007, “out of 55 available reports, three of the 11 regions reported that they had experienced considerable shortages, 32 reported that they experienced some shortages, and 12 of the regions reported having a balanced supply of technology education teachers” (Moye, 2009, p. 30). A review of the 2010, 2012, and 2013 AAEE documents report that there was a “balanced” demand and supply of technology teachers in the United States (AAEE, 2010, p. 5; AAEE, 2012, p. 58; & AAEE, 2013, p. 52). The 2016 document identified that there was “some shortage” of technology teachers in 2015. (S. Russell, personal communication, February 18, 2016).

The researcher surveyed state technology and engineering supervisors asking them two questions: (1) the number of middle and high school teachers employed in their state during the 2015-2016 school year, and (2) the number of vacant middle and high school technology and engineering positions during the 2015-2016 school year. The researcher was unable to find the contact information for six supervisors. Based on feedback from individual state departments of education, in at least three of the cases there was no technology and engineering supervisor assigned in those states. In one state, the science supervisor was assigned the technology and engineering supervisor responsibility.

After the initial email, the researcher sent a follow-up email to the supervisors. After both attempts to acquire information, only 11 supervisors provided the number of technology and engineering teachers in their states. Two supervisors provided documents that provided the number of Career and Technical Education teachers in their states, but being unable to discern one CTE area from another, that information was unusable. In some cases, supervisors indicated that they do not track the number of technology and engineering teachers currently employed or vacant positions in their state.

Concurrent with the follow-up email to supervisors, the researcher sent emails asking the same two questions to each state ITEEA Affiliate Representative and the President of each state technology and engineering education association. Although there were several responses from energetic teachers, only one could provide the researcher with the number of technology and engineering teachers in his state.

The researcher requested the number of employed teachers and vacancies in an attempt to compare that information to the numbers contained in past studies. However, because the researcher received so little information, he was unable to produce a reasonable list of the number of teachers and vacancies in the U.S.

Table 2. Technology Teacher Shortages Reported by State and Year

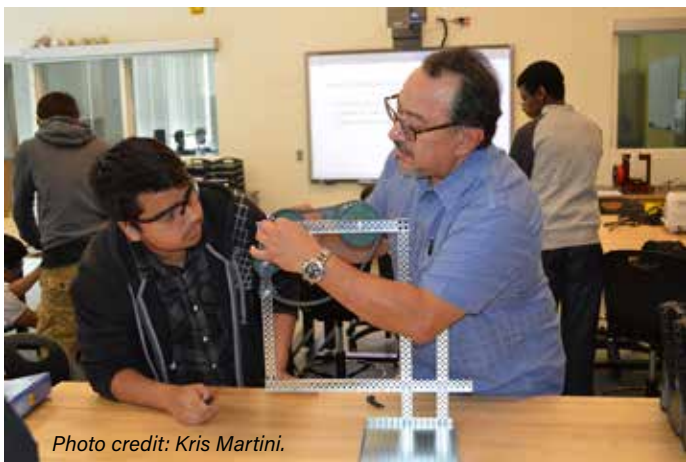
State	Years Shortages Reported					
	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16
CT	-	-	-	Y	Y	Y
DE	Y	Y	Y	Y	Y	Y
GA	Y	-	-	-	-	-
ID	Y	-	Y	Y	Y	-
IN	-	-	-	-	Y	Y
KY	Y	Y	Y	-	-	-
ME	Y	Y	Y	Y	Y	Y
MD	Y	Y	Y	-	-	Y
MN	-	-	-	-	-	Y
MO	Y	-	-	-	-	-
NH	Y	Y	Y	Y	Y	Y
NJ	Y	-	-	-	-	-
NY	Y	Y	Y	Y	Y	Y
ND	Y	-	Y	-	Y	Y
PA	Y	-	-	-	-	-
VT	Y	-	Y	-	-	-
WI	Y	Y	Y	Y	Y	Y
WY	Y	-	-	-	-	-

Included in all the email solicitations was a request for comments concerning technology and engineering teachers and programs in the states. The researcher received 53 comments from state supervisors, an ITEEA Affiliate Rep, and in one state, local division technology and engineering supervisors. Some individuals provided more than one comment. To determine recurring themes, the researcher coded (categorized) the comments.

Once coding was complete, several themes arose. Occurring 20 times, the theme that received the most comments was the shortage of available technology (and engineering) teachers. The area receiving the second most comments identified program closures, seven of which were technology and engineering teacher education programs and five secondary school program closures. The third most common comment (seven) identified how positions were filled with alternatively licensed teachers “crossing over” from industry. Two comments identified problems with or lack of state-level leadership. Other information discussed the need for improved teacher professional development and that teachers are not willing to participate in professional development. Also mentioned was the need to transform programs to include robotics and other STEM-related activities.

Discussion

The purpose of this study was to determine the supply and demand of technology and engineering teachers in the United



States. This study did not collect the information as planned, but a few conclusions can be made.

Recent studies on the subject have experienced little success determining the number of technology and engineering teachers employed and the number of vacancies in the states. Questions technology and engineering education professionals should ask: Is it important to determine the supply and demand of technology and engineering teachers, and if so, why is it important? In this author's opinion, it is necessary to determine if the supply is meeting the demand and if the demand is increasing or decreasing. Further—is there even a demand at all?

Over the past two decades, the supply of technology and engineering teachers has declined dramatically. In the 1995-96 school year, institutions produced 815 new technology teachers. In 2015-16, the number of graduates declined to 206, one quarter of the graduates produced 20 years prior.

A review of USDOE *Teacher Shortage Areas Nationwide* list from 2010 through 2016 reveals a shortage of technology/design and technology teachers in only 58 of 300 possible incidences. The American Association for Employment in Education reported a "balanced" supply and demand of technology teachers in the United States during the years of 2010, 2011, and 2012. In 2015, there was "some shortage" of teachers. These national documents suggest that between 2010 and 2016 there was no substantial shortage of technology and engineering teachers in the United States. This suggestion contradicts the comments that technology and engineering leaders' provided for this study.

Even though Martin and Ritz (2012) found that determining the supply and demand of technology and engineering teachers in the U.S. was not a concern of those surveyed, many professionals do consider this a problem. This study found at least three issues that should be addressed. The first is the lack of technology and engineering teachers produced in universities across the nation. The data show that over the past 20 years there are fewer institu-

tions producing fewer teachers. The second issue is that national documents suggest that there is no technology and engineering teacher shortage when leaders in the profession think that there is. The third issue is the lack of data showing how many teachers are employed and teacher vacancies in each state.

Assuming the national teacher shortage data is accurate and there is no substantial demand for technology and engineering teachers: is it true that there is no demand? With the substantial decline of technology and engineering teachers graduating annually, why wouldn't there be a shortage? Could it be that states are not correctly reporting those shortages or there is not real shortage because of program closures?

It is this researcher's opinion that the technology and engineering profession is in a very difficult predicament. If the number of teachers and programs continue to decline (as reported), the future of the profession itself is at stake. Therefore, no other problem is as important to research and solve. The fact is, we in our profession realize that the supply and demand of technology education teachers is at a critical point. But, what are we doing about it?

Recommendations

Recommendations for further research. Researchers should:

1. Complete a detailed and accurate study of the supply and demand of technology and engineering teachers in the United States.
2. Determine why students are not entering the technology and engineering teaching profession.
3. Find the "best practices" that encourage students to enter into the technology and engineering teaching profession.

Conclusion

The supply and demand of technology and engineering teachers continues to be of concern. Researchers have successfully conducted studies to determine the number of teachers graduating from teacher education programs but have found limited success when attempting to determine how many technology and engineering teachers are employed in the United States. Further, it has been equally difficult to determine how many vacancies exist.

This report does not attempt to show how our profession is dying. It reiterates what our profession's leaders have stated for decades. We have a teacher supply-and-demand problem! However, it is very difficult to determine the actual extent of the problem, and if a problem even exists. Concerning the supply and demand of technology and engineering teachers in the United States, who really knows?

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The Learn Better by Doing Study needs YOU (even if you have participated before)!

The researchers are currently conducting Round 4 of this study, designed to determine the extent to which U.S. public school students are doing hands-on activities in their classrooms.

Elementary and secondary STEM teachers are encouraged to participate in this study by following this link: www.iteea.org/Activities/2142/LearningbyDoingProject.aspx. Participation deadline: April 15, 2017.

overcrowding

in K-12 STEM classrooms and labs

There is a statistically significant correlation between overcrowding and increased accident rates.

**MAXIMUM
OCCUPANCY
NOT TO EXCEED
PERSONS**

Background

Overcrowding in science, technology, engineering, and mathematics (STEM) classrooms is the number one safety concern among STEM teachers (Horton, 1988; Macomber, 1961; Stephenson, West, Westerlund, & Nelson, 2003; West & Kennedy, 2014; West, Westerlund, Nyland, Nelson, & Stephenson, 2002). Indeed, there is a statistically significant correlation ($p < 0.001$) between overcrowding and increased accident rates as seen in Figures 1 and 2 based on a study of 270 accidents (Stephenson et al., 2003; West & Kennedy, 2014). Overcrowding can occur in any type of room where STEM activities occur such as labs or classrooms or combination lab/classrooms or makerspaces.

Overcrowding Defined

While overcrowding has long been linked with accidents in all types of STEM rooms, it is more complex because overloading STEM classes manifests itself in three very different ways including occupancy load, class size, and the amount of workspace per student. Another factor that needs to be considered is the difference between a "combination classroom/laboratory or workspace" or "makerspace," and a "pure laboratory or workspace" or "makerspace" where different activities occur in each area. Only hands-on laboratory investigations or activities occur in a "pure laboratory," whereas in a combination classroom/laboratory, only non-lab instructional activities occur in the classroom area. This distinction is important when determining space limitations. States such as Texas, Massachusetts, Vermont,

California, and Georgia have requirements that limit class sizes using different criteria such as their state facilities standards.

Occupancy Load: Overcrowding is defined and regulated by the National Fire Protection Association (NFPA) Lab Occupancy code. The STEM laboratory is considered a vocational subject area by NFPA. Fifty (50) square feet of net free space per person (not just students) is the amount of space required as per the provisions of the NFPA 101 Life Safety Code®. Note this regulation refers to a pure laboratory/room that is used only for hands-on STEM activities, not typical classroom activities such as lectures or group/individual activities. This regulation typically applies to the amount of space in the lab area of the combined type of room. This limitation is primarily a safe egress regulation in case of fire.

Class Size: Class sizes greater than 24 (in any one class) limits a teacher's ability to supervise a large number of students doing STEM activities with hazardous chemicals, materials, tools, or equipment. Overcrowding in regard to supervision likely affects a teacher's ability to properly manage and oversee his or her classroom, and therefore may prevent the adequate supervision of students conducting STEM activities. Interestingly, professional science teachers' organizations have long recommended limiting science class sizes to 24 occupants if the room is of adequate size to accommodate the needed individual space. This recommendation could be applied to technology and engineering education laboratories since they are also categorized as vocational subject areas by NFPA. Moreover, since technology

by
Sandra S. West

and engineering education tends to use more hazardous equipment, it would seem judicious to use an even lower maximum class size than 24 students for those classes. A student/teacher ratio above the research findings and professional standards creates greater risk of accidents for students and their teachers. Accidents significantly ($p < 0.001$) increase as the class size increases (Stephenson et.al., 2003; West & Kennedy, 2014; West, et.al., 2002) (Figure 1).

Workspace per student: A lack of individual workspace or “elbow room” per student is also linked to increased accident rates. As STEM students are working with hazardous chemicals (ACS, 2012), materials, tools, or equipment, adequate individual workspace is required to be able to move freely and work safely. Accidents significantly ($p < 0.001$) increase as the amount of space per student decreases (Stephenson et.al., 2003; West & Kennedy, 2014; West, et.al., 2002) (Figure 2).

Recommendations

Work with your school and district administrators, local and state school boards, teacher and administrator organizations, and your local Fire Marshall to better understand the research, requirements, and professional standards to ensure that students and teachers are provided safer learning and working environments. For additional safety-related information, see the issue papers from the National Science Teachers Association (NSTA, 2016) and ITEEA’s comprehensive safety guide (DeLuca, Haynie, Love, & Roy, 2014).

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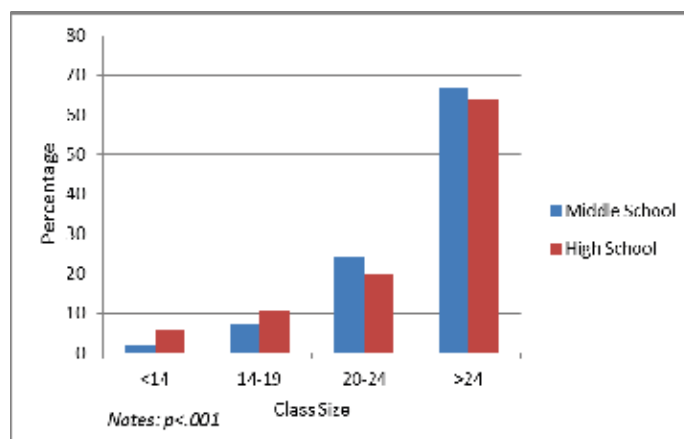


Figure 1. Relationship between percentage of accidents that occur and student/teacher ratio.

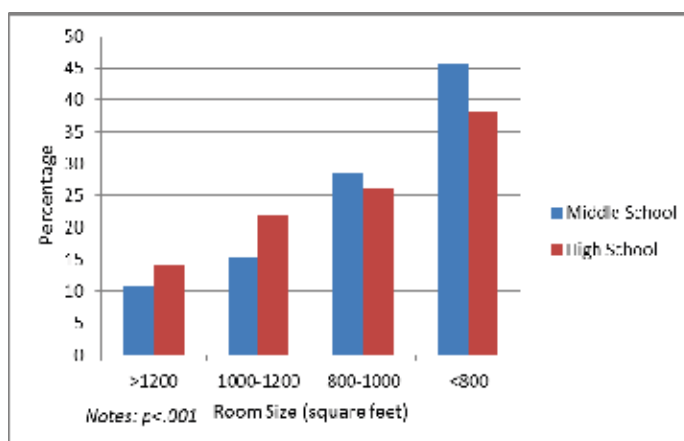


Figure 2. Relationship between percentage of accidents that occur and space per student.

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Sandra S. West, Ph.D., is an associate professor of Biology and Science Education at Texas State University and the Legislative Liaison for the Science Teachers Association of Texas. She also serves on the National Science Teachers Association (NSTA) Safety Advisory Board and the International Council of Associations for Science Education Safety Committee. She can be reached at sw04@txstate.edu.

Have questions or a safety issue that you would like to see addressed in a future Safety Spotlight article? Please send them to Dr. Tyler Love at tslove@umes.edu.

The Mushroom-Growing Challenge

by Harry T. Roman

Introduction

Mushrooms are a tasty addition to any meal, but often expensive. So why not grow them for local markets? How might this be done on a large-scale basis?

How about using old red brick factory buildings—those with multiple, sturdy floors that perhaps once housed heavy equipment and manufacturing facilities? Cities generally have a number of these buildings, either empty or abandoned, that could be recycled for other uses...perhaps for growing shade-preferring mushrooms!

Examining the Problem in Detail

Let's start with a three-level red brick facility, with a full basement and two above-ground floors. This shall be our initial design challenge basis. The basic problem is: How do we convert an old manufacturing building to an enclosed mushroom-growing facility?

First we need to establish some student teams so we can know something about growing mushrooms—their soil preferences; growing-maturation times; kinds that are desired by restaurants and home kitchens; quality and safety of mushrooms being grown, etc. This is best approached with students performing in-depth internet research.

How are mushrooms grown commercially today? Has anyone tried to grow them indoors? How has this worked? What are the chief concerns and experiences?

Using a typical red brick factory building as a starting point, how can it be converted to an indoor farming area for mushrooms—specifically:

- How much soil would be needed?
- How much might all this soil and entrapped water weigh?
- Can the old factory floors support this weight?

Seems like your student teams need to know something about how old factory buildings and floors were constructed as well as their structural design and load-bearing capabilities. Generally, these structures were designed to support 125-250 pounds per square foot of floor area—but this needs to be checked. Has age possibly weakened these original load-bearing figures? Are there structural engineers and architects who have looked into this? Old factory buildings are converted to condominiums and artists' lofts in many cities. How are floor-loading issues handled—and how might this relate to an indoor mushroom-growing facility? Have similar buildings been converted to living spaces in your city/town? Might your town engineer have time to talk with your student teams?

- How would the mass of soil be irrigated and drained?
- What kinds of lighting might be employed—natural, shade, artificial?
- How about temperature control for the mushrooms as they grow?
- Will pesticides be required?

Low-cost greenhouses are very popular for ornamental plants. Is there some technology that can be transferred to growing mushrooms inside old buildings? Where are the similarities and differences between greenhouses and our discussion about indoor farming?

- With all the indoor moisture, wet soil, and potential for airborne fungus...does this present a problem for human workers?
- Could the mushroom-growing process be automated?
- What monitoring and safety features might need to be installed?
- Does this facility need to be air-conditioned for occupancy by humans?
- Does your municipality have special codes and standards governing indoor greenhouses, e.g., standards that must be complied with?

Expressing a Design

Students should make extensive use of diagrams and illustrations to describe how this facility would look and operate. Written reports by the teams should discuss:

- Costs, both fixed and operational, for their design.



- Impacts on the neighborhood where the old factory is situated.
- Potential jobs for local inhabitants.
- Potential mushroom sales and profits.
- Customers who will purchase the mushrooms.
- Branding the mushrooms with their own corporate identity.
- Marketing the mushrooms—where sold and why?
- Harvesting and packaging the mushrooms for sale.
- Trucking the mushrooms to market.

Students should be encouraged to make cardboard models of the revamped old factory building. Architectural students do this regularly. Would it be worthwhile to invite college-level architectural professors and students into your classroom to discuss what your student teams are doing and to offer some guidance and mentorship?

Other Thoughts

Here are some provocative additional thoughts for your teams to consider:

- Can other valuable crop varieties also be grown in this facility?
- Is there a role for alternate energy technologies to play in the renovated facility?
- Can this special re-use of old city structures inspire other types of facilities?
- Is this a viable way to renew an old urban industrial base?

Engage your students in this real-world problem. Empower them to use their imaginations and creativity.

They may never see mushrooms the same way again!



Harry T. Roman is a retired engineer/inventor and author of technology education/STEM books, math card games, and teacher resource materials. He can be reached at htroman49@aol.com.



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