SAFETY SPOTLIGHT
P. 36

TEACHER RECRUITMENT
(including classroom poster!)

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Mastercam allows my students to go farther and learn faster. The intuitive nature of the software gives students the confidence to succeed and the tools to prosper. Most of my students do more with Mastercam than the curriculum dictates. One student went as far as to take a CT scan mesh of their own skull and turn it into an actual machined part. Intuitive software, an easy to learn interface, and amazing customer service make Mastercam my software of choice.

– Instructor Brian Nelsen, Dunwoody College of Technology, Minneapolis, Minnesota

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ITEEA is building on the success of the DC conference as we continue the planning for Dallas 2017 in earnest! The Dallas Conference theme is “Engaging and Empowering Decision Makers Through Integrative STEM Education.” Decision makers include all those with a stake in the education of our students as well as those with the power to influence its future. Decision makers are students, parents, our communities, and political decision makers. The 2017 DC Conference theme and strands were chosen to provide a vehicle for educators to learn more about and share their experiences.

With over 100 learning sessions, preconference workshops, the STEM Showcase, the latest products and services, student competitions, and MUCH MORE, the 2017 Dallas conference offers an unparalleled integrative STEM professional development opportunity.

It’s not too late to be a STEM Showcase presenter—capitalize on the opportunity to share your knowledge with your colleagues while creating some great PR for your program! The STEM Showcase provides a forum to feature your best exemplar of technology and engineering instruction. Apply by October 1 at www.iteea.org/ITEEA_Conference_2017.aspx.

Want to apply for—or nominate someone for—an ITEEA award or scholarship? The deadline for most is December 1—and awards and scholarships will be presented in Dallas. Apply today at www.iteea.org/AwardsScholarships.aspx.

Watch the ITEEA website for information about preregistration, which is opening SOON! Preregistration provides numerous benefits including saving TIME and MONEY as well as eligibility for a $100 Visa gift card.

Preregistration is opening soon!
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TETe: INNOVATE THE INTERSECTION OF ENTOMOLOGY AND TECHNOLOGY
An integrated STEM unit created to provide teachers with an instructional model meant to demonstrate how linking all the elements of STEM, through an uncommon intersection, can generate a lesson that is meaningful, engaging, and effective in improving student learning of STEM content.
By Geoff Knowles, Todd Kelley, and Blake Hurd

On the cover: Scott Didra, T&E teacher at Emmaus High School in Pennsylvania, helps students design a model playhouse. During his 34 years of teaching, Scott has influenced 15 of his students to become T&E educators.

BETTER PRACTICES FOR RECRUITING T&E TEACHERS P.10
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By Tyler S. Love, Zachary J. Love, and Kevin S. Love

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The fourth report of the Learn Better by Doing study, which presents data found in rounds one, two, and three and provides information concerning the future of the study.
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CONNECTING STUDENTS’ BACKGROUND EXPERIENCES TO ENGINEERING DESIGN P.30
By rigorously incorporating students’ funds of knowledge, TE teachers show students that engineering is relevant to their everyday lives and can be used to solve problems and make a difference in the world around them.
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It's a New School Year!
Top 10 Ways to Network, Network, Network!


Technology and Engineering Teacher, Children's Technology and Engineering, and the Journal of Technology Education will keep you up to date on the latest developments in the field. [www.iteea.org/Journals.aspx](http://www.iteea.org/Journals.aspx)

STEM Connections is a FREE, cutting-edge electronic newsletter packed with information pertaining to STEM education. [www.iteea.org/STEM_Connections.aspx](http://www.iteea.org/STEM_Connections.aspx)

ITEEA’s Headliner provides a brief update of some of the current projects, membership activities, and other events with which ITEEA is involved. [www.iteea.org/Headliner.aspx](http://www.iteea.org/Headliner.aspx)

The ITEEA Peer Mentoring Taskforce seeks individuals to serve as mentors to new ITEEA Members as well as those whom feel they would benefit as mentees—ITEEA Members growing professionally. [www.iteea.org/Mentoring_Program.aspx](http://www.iteea.org/Mentoring_Program.aspx)

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The forum that generates real-time dialogues about all things STEM. IdeaGarden is a “Members Only” forum. If you’re a member, you’re part of the conversation. [www.iteea.org/Ideagarden.aspx](http://www.iteea.org/Ideagarden.aspx)

ITEEA “tweets” about STEM education headlines, resources, opportunities, and special offers exclusively for followers. Follow ITEEA at [https://twitter.com/iteea](https://twitter.com/iteea).

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The 2016-2017 ITEEA Board of Directors election ballot, including candidate biographies, will be emailed to Professional and active Life Members in late September. The highly experienced field of candidates is pictured here. Exercise your right to vote by completing your ballot promptly! Ballots must be completed on or before October 30, 2016. Be sure that ITEEA has your correct email address—to review or update it, log on to your member profile on the ITEEA website at www.iteea.org.
maximizing membership

I recently read a blog post by a company called 4C Technologies that really hit the mark in terms of describing the "Top 10 Reasons to Join a Professional Organization." Below, I take those top 10 reasons to join and have tailored them to how ITEEA achieves and exceeds in terms of what members value. And while I hope each of you is familiar with all of the benefits of ITEEA membership detailed below, I suspect you might find a few that you weren’t even aware of.

1. **Broaden your knowledge.** ITEEA is working to create several new avenues for member education in the 2016-17 school year. We’re introducing a webinar series that kicks off in August, which is FREE to ITEEA members. The first in the series, which took place recently, was hosted by Jorge Valenzuela of Richmond Public Schools on the topic “Authentic Project-Based Learning in Technology and Engineering Education.” In addition to the free webinar series is a complete series of PLCs (Professional Learning Communities) on a broad range of topics including “Nature of and Definition of I-STEM Education, Maximizing Your STEM Lab: Best Practices, and Whole School Engagement: Funding Your Integrative STEM Education Initiatives.” PLCs are scheduled for each month from now until June (ITEEA members receive a registration discount).

2. **Take charge of your career.** Did you know that ITEEA has a website area called “Career Connection”? This is a resource dedicated to matching those who are seeking employment with those who are seeking qualified employees. The webpage allows employers to post job opportunities as well as ITEEA members to post resumes.

3. **Build a better resume.** In addition to being able to list your membership in an international professional association on your resume, ITEEA and its Foundation for Technology and Engineering Educators (FTEE) give awards and scholarships to support the advancement of technology and engineering education. Scholarship opportunities exist for members who are current graduate or undergraduate students, teachers, and/or veterans. Literally thousands of dollars are awarded to ITEEA members each year. Members can also apply for—or nominate someone for—awards such as Program and Teacher Excellence, Emerging Leader, and Distinguished Technology and Engineering Educator.

4. **Enhance your network.** I encourage you to flip back to page 5 of this journal, where you will find a terrific list of no fewer than TEN ways you can “up” your networking via ITEEA. Whether you choose to follow ITEEA on Facebook (where you will find resources and news on an almost daily basis), participate on ITEEA’s IdeaGarden forum (a unique resource where educators can ask—and answer—questions on a variety of topics), or attend an ITEEA conference (which includes the extra networking bonus of taking part in the STEM Showcase), the networking opportunities are numerous and effective!

5. **Be a leader.** Membership in ITEEA offers countless opportunities to develop or enhance leadership skills. ITEEA could not function without the dedication of countless volunteers. The association is regularly looking to add individuals to its standing Committees (e.g., Awards, Conference Programming, Membership), and its Review/Management Boards (e.g., Emerging Leader, Distinguished Technology and Engineering Professional, Technology and Engineering Teacher). As a committee member, you have a stronger voice in the future of ITEEA and its membership, awards, publications, and more. You can also hone leadership skills by applying to present as either a session leader or a STEM Showcase participant. Both provide the opportunity to raise your professional profile within the organization.

by
Kathleen B. de la Paz
should consider helping to lead the association as a Board of Directors member.

6. **Become a mentor.** ITEEA has been working to build its Peer Mentoring Taskforce and seeks individuals who are willing to serve as mentors to new members—as well as those who feel they could benefit as mentees. The mentoring program allows current and future ITEEA members to grow and learn through the mentoring process and helps them become key professionals working to make a difference. Mentors and mentees assist one another and the larger profession by becoming involved with the larger picture of education.

7. **Make a new friend.** There are a number of ways to make personal contacts within ITEEA. One great way, albeit electronically, is via the IdeaGarden forum. This tight-knit group of educators get to “know” one another by regularly offering one another information, insights, and support. Each year at the ITEEA conference, the “Gardeners” come together for a special session where they always enjoy putting names to faces. And speaking of the conference, each year we build in plenty of activities geared towards helping people get to know one another, including a networking reception, tours, and food functions.

8. **Give back to the community.** The ITEEA community can always use your talents and experiences. As was stated earlier, we couldn’t function without our army of volunteers. These volunteers are the backbone of the association and give freely of their time and talents to assist in numerous ways. Those great articles you read in *Technology and Engineering Teacher* and *Children's Technology and Engineering*? Each one was volunteered. Remember checking in at the ITEEA conference? The vast majority of the folks behind the counters were volunteers. Almost all of the conference presenters are volunteers. Eleven out of twelve members of the Board of Directors are volunteers.

9. **Strength in numbers.** As an ITEEA member, you have access to like-minded individuals with whom you can more easily achieve your shared goals for the profession. ITEEA works tirelessly on your behalf to create partnerships that are intended to benefit both members and the field. Here is a short list of just a few of the partnerships created by ITEEA within the past few years:
   a. **National Science Teachers Association.** ITEEA has partnered with NSTA on several key initiatives, including the July 2016 STEM Forum and as part of a project to establish top “STEM trade books.” Also, ITEEA’s Safety Expert has been named to the NSTA Safety Board, thereby ensuring the appropriate representation of technology and engineering classroom and lab safety.
   b. **Technology Student Association.** ITEEA has visibly increased its presence at the annual TSA conference, and in July of this year, led the TSA National Problem Solving Event. ITEEA and TSA regularly collaborate on a variety of efforts that benefit members of both associations.
   c. **LinkEngineering.** ITEEA has partnered with the National Academy of Engineering, NSTA, ASEE, and others in the creation of the LinkEngineering website—an online community of educators interested in providing meaningful engineering experiences to PreK-12 students of all abilities.
   d. **American Society for Engineering Education.** A reciprocal arrangement in which ITEEA and ASEE support one another’s conferences as partners—as exhibitors, advertisers, and via website presence.
   e. **Society for American Military Engineers.** Through this partnership, SAME helped to add 25 District of Columbia Elementary Schools with limited resources as ITEEA Elementary School Members.

10. **Stay inspired and stay motivated.** It is my hope and goal that each of you will take just a bit of time to DISCOVER some new aspect of your ITEEA membership. There are myriad opportunities and benefits associated with being part of this organization, and it just makes sense to MAXIMIZE what you are paying for. In case you haven’t heard, ITEEA launched a completely “re-engineered” website early this year, and it boasts tools that every member should be taking advantage of. I see ITEEA members finding inspiration and motivation every single day—but the key is something I tell my kids about school: “You get out of it what you put into it.” ITEEA has a long and proud history. Just imagine what it can achieve if EVERY member found ways to both support his or her career, and also to contribute to his or her ITEEA colleagues.

It has been an honor and privilege to work on your behalf for nearly two decades. I’ve said it before but I’ll say it again: ITEEA members are my heroes! You are the front line in the effort to make tomorrow’s citizens technologically literate—and therefore better positioned to make educated decisions about their (and our) future. If I can ever be of assistance to anyone in any way, please do not hesitate to contact me at the address below. Have a wonderful school year!

**Reference**


Kathleen (Katie) de la Paz is Editor-in-Chief and Director of Communications of ITEEA. She can be reached at kdelapaz@iteea.org.
Attention Teachers: Help Needed Recruiting Future T&E Educators!

Introduction

The declining number of Technology and Engineering (T&E) educators and teacher preparation programs across the country has been identified as a critical issue plaguing the field for many years (Daugherty, 1998; Volk, 1993). Unfortunately, this issue continues to progress and has raised concerns. Why should middle and high school T&E educators be concerned? The answer is simple: teachers have been identified as the most influential factor in encouraging students to pursue T&E education as a career. Without current educators helping universities to recruit future T&E teachers, many programs face the grim reality of closure for enrollment and budgetary reasons. This article presents 14 strategies supported by research and recent recruitment efforts that teachers should use to encourage students to become T&E educators.

Declining Program and Graduation Trends

Numerous researchers have examined issues surrounding T&E educator shortages. The number of universities offering degrees in industrial arts (IA), technology education (TE), or T&E education has plummeted from 203 in 1970 to its current status of 43 institutions (Rogers, 2015; Volk, 1993; Warner, Erli, Johnson, & Greiner, 2007) (Figure 1).

by

Tyler S. Love,
Zachary J. Love,
and Kevin S. Love

Image Caption: Scott Didra of Emmaus High School is pictured with his students’ successful playhouse project. This project influenced some of his students to major in T&E education.
As a result of declining programs, the number of IA/TE/T&E education graduates has decreased significantly, from 6,368 in 1970 to 245 in 2015 (Rogers, 2015; Soboloski, 2003; Volk, 1993) (Figure 2).

The significantly decreasing number of programs and graduates is alarming given the trends regarding increasing demands for T&E educators and decreasing supply of qualified teachers (Moye, 2009). Daugherty (1998) cautioned the field about this issue almost 20 years ago:

The urgent need to recruit, prepare, and retain significantly more teachers in technology education is clear. At the same time the population of teachers entering the field is decreasing, the number of teaching opportunities and number of secondary students enrolling in technology education programs is increasing. The low number of individuals entering technology education teacher preparation institutions threatens not only post-secondary programs, but the very fabric of the profession through the closing and consolidation of programs (p. 22).

Previous Recruitment Strategy Studies

Over the past 50 years various studies have surveyed teachers, undergraduate students, alumni, department chairs, professors, and state supervisors, examining the factors that influence students to become T&E educators. Consistent throughout the literature, many studies have found classroom teachers to have a strong influence on recruiting students to enroll in undergraduate T&E education programs. The latest study on T&E education recruitment factors examined traditional methods as well as newer social media sources. Love’s (2014) study found that even with technological advances in recruitment resources, undergraduate T&E education students reported their middle or high school T&E educator as the most influential factor regarding their decision to become a T&E teacher (Table 1). More than 86.2% of the students in this study expressed that personal interactions with teachers, recruiters, alumni, and family members significantly influenced their decision to enroll in a T&E teacher education program.

Also consistent with previous research findings, Love (2014) found that high school counselors had very little influence on persuading students to enter T&E education programs. This may suggest that T&E education teachers need to work more closely with counselors at their high school to inform them of what T&E education is and how critical it is for enhancing STEM literacy.

Table 1
Factors Influencing Students to Enroll in a T&E Education Program (Love, 2014)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Avg. Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle/High School T&amp;E Education Teachers</td>
<td>5.29</td>
</tr>
<tr>
<td>Hands-On Hobbies</td>
<td>4.76</td>
</tr>
<tr>
<td>Positive Job Characteristics</td>
<td>4.63</td>
</tr>
<tr>
<td>Interactions With Alumni</td>
<td>4.51</td>
</tr>
<tr>
<td>Face-to-Face Interaction With Someone</td>
<td>4.49</td>
</tr>
<tr>
<td>Family Members</td>
<td>3.30</td>
</tr>
<tr>
<td>Current T&amp;E Education Student in the Program</td>
<td>2.94</td>
</tr>
<tr>
<td>Friends and Peers</td>
<td>2.59</td>
</tr>
<tr>
<td>University Website</td>
<td>2.65</td>
</tr>
<tr>
<td>University Open-House Event</td>
<td>2.49</td>
</tr>
<tr>
<td>High School Counselors</td>
<td>2.20</td>
</tr>
<tr>
<td>Technology Student Association (TSA)</td>
<td>2.18</td>
</tr>
<tr>
<td>Program Brochures</td>
<td>2.14</td>
</tr>
<tr>
<td>University Recruiter Visiting High Schools</td>
<td>1.47</td>
</tr>
<tr>
<td>Facebook Page</td>
<td>1.29</td>
</tr>
<tr>
<td>Twitter/Instagram Accounts</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Note: These ratings represent Likert scores ranging from 1 (no influence) to 6 (main influence).
Teachers’ awareness of findings and trends from recruitment studies is important for better informing their efforts.

Two Teachers’ Success Stories

Two teachers shared their recruiting successes using some of the strategies from the aforementioned studies. At last year’s Technology and Engineering Educators Association of Pennsylvania (TEEAP) conference the authors met Allen Androkites and Scott Didra. Allen teaches T&E education at Pennridge High School, and Scott at Emmaus High School, both in Pennsylvania. In 35 years of teaching, Allen has had 28 students become T&E educators, and in Scott’s 34 years of teaching, he said he has had 15 students become T&E teachers, including his daughter.

Allen Androkites of Pennridge High School has influenced 28 students to become T&E educators during his 35 years of teaching!

When we asked Allen how he has been able to influence so many students into becoming T&E teachers, he shared this advice: “My teaching philosophy is simple—the more you give, the more you get. T&E teachers need to show that they love their job, and they need to promote it.” Allen believes it is critical for T&E educators to have a positive outlook about teaching on a daily basis and convey that message to students. He also shared some methods that he has found successful:

I look for students in their sophomore and junior year who believe have the personality to be a teacher, especially in T&E education. I have had great success encouraging student athletes to major in T&E education. I ask them, ‘Do you like what you’re doing in my class? You can get paid to do something fun like this for a career while also coaching high school sports.’

Allen has contacted parents of students who have shown interest in his courses and have done well, encouraging them to have their child sign up for the next level T&E courses. When speaking with parents, Allen informs them of the job opportunities available and describes why their child would be an excellent T&E teacher. From his experience, many parents were thankful for his advice because they did not know much about T&E education as a career. Furthermore, when school counselors asked for course recommendations, Allen provided names of those students who had shown progress in his courses so they would be encouraged to take more T&E classes. This has provided Allen a chance to further develop students’ passion for T&E education and persuade them to pursue it as a career.

Scott Didra provided some similar insight regarding what he has found successful for influencing students to become T&E educators:

After I saw Millersville University at our state conference presenting data about the shortage of T&E teachers, I took that information back to my classroom, displayed it, and discussed it with my students. I asked them ‘Do you like what you do in this class?’ They responded yes, and then I told them that they could continue to do this and get paid for it. They were unaware that was a career option.

One strategy Scott found to be the most successful was allowing his students to teach and learn from each other:

To teach is to learn. We must give our students opportunities to be a leader and a teacher to help change kids’ lives. My students embrace that leadership/teaching role, and they love it. I currently have one high school student who is like a student teacher in my classroom. From that experience he has decided to change his career plans from engineering to T&E education. When students realize they have taught their peers something new, that is when you can see the light-bulb go on, and they gain a sense of satisfaction in helping others.

Scott’s students consistently mention how much they enjoy the family atmosphere and professionalism of his courses, which they refer to as “The Firm.” His inspirational teaching style was featured in a Discovery Education webinar video (East Penn School District, 2016).
Strategies for Teachers to Help Recruit

Ritz (1999) described many useful methods for classroom teachers to encourage students to become T&E educators, and Daugherty (1998) provided an innovative perspective in which he proposed 51 strategies that mimicked the recruiting guidelines set forth by the National Collegiate Athletic Association (NCAA). While the methods from the aforementioned articles can still be effective today, 14 strategies were generated from the review of literature, interviews with Allen and Scott, and our personal recruiting experiences at the secondary and postsecondary levels.

1. **Raise Awareness of Your Program**
   For years T&E educators have had to raise public awareness about their programs to increase enrollment in elective T&E courses. Promoting secondary level T&E programs also raises awareness about the profession and can introduce students to T&E education as a career. Displaying innovative student projects in your school’s trophy case and promoting students’ exemplary work through your school’s newsletter, social media accounts, and local media sources can help raise awareness of T&E education programs. One example of a newer T&E topic of great interest to the public and that should be showcased is 3D printing. There are a number of other methods that can help publicize T&E programs at no cost (Caccavale, 2016). Furthermore, Daugherty (1998) recommended 14 activities that can help T&E teachers enhance the image of their program, and Scarcella (2000) presented strategies for marketing T&E education programs. As T&E educators, we must take responsibility to promote our programs and show we are an integral component of STEM.

2. **Advertise Nearby College Programs**
   There are a number of colleges where students can earn licensure to teach T&E education. As alumni, teachers may already have connections with these college programs. Most students are not aware of where they can obtain a T&E education degree. Teachers should help inform students of their choices by contacting T&E education faculty at nearby universities to send promotional materials to their school. These items should be displayed in T&E classrooms/labs, school hallways, and school counselor offices to reach all students. Some programs have their promotional materials readily available on their website for teachers to print (e.g., UMES, 2016), but most would be more than happy to mail materials if requested. The poster accompanying this article should be displayed to interest individuals in teaching T&E while also informing them where they can earn their degree (see insert or download from www.iteea.org/BetterPracticesforRecruitingTandETeachers.aspx).

3. **Collaborate with Your School Counselors**
   Building on the previous strategy, providing your school counselors (formerly called guidance counselors) with the promotional materials you received from T&E education programs is critical. In many recruitment studies, especially the latest by Love (2014), school counselors were not found to have a significant influence. This may be due to misconceptions counselors have about what T&E educators do. From the authors’ experiences, school counselors have proven supportive of T&E education as a career once they fully understood what T&E education is, the demand for T&E teachers across the country, and where students can earn a degree. One way to start this conversation with your school counselors is to share literature such as this article or Moye’s (2009) article demonstrating the increasing demand but decreasing supply of qualified T&E educators. It is beneficial to have a discussion with school counselors as opposed to simply emailing or dropping off promotional materials.

4. **Notify Parents of Opportunities for Their Child**
   Parallel to working with school counselors is communicating T&E education career opportunities to parents. Back-to-school night and parent-teacher conferences provide perfect opportunities to introduce this topic. Students who show an interest in T&E courses and are undecided on a career path would be prime candidates to recruit. Speaking with parents to reiterate the need for T&E teachers can prove helpful. When emailing or calling parents to notify them of the exemplary work their child has done, teachers should ask if their child had ever considered becoming a T&E teacher because of their interest and success in the course, ample job opportunities, and other benefits of the profession.

5. **Incorporate It In Your Courses Throughout the Year**
   Many courses and textbooks highlight a career connection related to the topic being studied. T&E education is no different; it should be integrated as a career option that students research and present. Infusing T&E education careers into multiple units can be accomplished by asking students to research and present. Infusing T&E education careers into multiple units can be accomplished by asking students to research and present innovative methods that T&E educators could use to teach unit topics. Simply presenting T&E teaching opportunities as a one-day, drive-by experience is not as effective as incorporating it into the course multiple times throughout the year.
better practices for recruiting T&E teachers

6. **Allow Students to Teach T&E Lessons**
   In many courses, students are taught information presented by the instructor. They are expected to present their research and design solutions to the class, but rarely are students required to teach a T&E topic to the class. Allowing students to teach a lesson to their peers or demonstrate their design solutions to elementary/middle school students within your school district can provide a preview of how rewarding it is to teach T&E education. This also serves as a good recruitment tool to enhance enrollment in elective T&E courses.

7. **Take Students to T&E Conferences/Events**
   Teachers should work with their school system to provide transportation to a state, regional STEM, or ITEEA conference. Many of these events have a significantly reduced registration rate for students to attend. Students should be encouraged to present with the instructor about their best T&E activity. This could be done in a less intimidating atmosphere like the STEM Showcase portion of ITEEA’s conferences. Finding a way for students to attend a T&E education conference or event allows them the opportunity to see all of the innovative things going on at other schools and network with inspiring teachers and students. It serves as a vehicle to rejuvenate their excitement for T&E education, and they will be more inclined to get involved with the organization and attend the event again.

8. **After-School STEM Clubs**
   Students participating in after-school, STEM-related clubs often do so because they enjoy doing hands-on STEM activities. This was the second greatest factor influencing students to become T&E educators in Love’s (2014) study. Serving as a coach/mentor/advisor for TSA, SkillsUSA, 4H, state engineering competitions, or Science Olympiad clubs is a great opportunity to interact with STEM-motivated students and introduce them to the benefits of being a T&E teacher. Even helping or guest-speaking to these clubs periodically provides a valuable opportunity to recruit students for your T&E courses and T&E teacher preparation programs.

9. **Collaborate with Educators Rising Clubs**
   Formerly known as the Future Teachers of America, the Educators Rising club is a nationally sponsored organization rich with opportunities for recruiting students into T&E education. Negative public perceptions about teaching careers have been cited as the cause for decreased enrollment in education programs across the country. However, in this organization students have already identified an interest in becoming educators. The key is to hook them into T&E education by demonstrating the exciting hands-on teaching opportunities in our field. Serving as a faculty sponsor or presenting information about where to obtain a T&E education degree can raise awareness about teaching T&E concepts and collaborating with T&E educators. You can also influence students to refocus their interest from an oversaturated teaching field (e.g., elementary education) to the critical-shortage area of T&E education.

10. **Collaborate With Local Engineering Clubs**
    Local chapters of professional engineers can be beneficial in multiple ways. Establishing connections with members of these organizations provides opportunities for engineers to increase students’ interest in T&E topics while serving as mentors or presenting information about where to obtain a T&E education degree. Lastly, these clubs often have scholarship funds for students interested in pursuing an engineering-related degree. This would provide some incentive for students to major in T&E education and offset the cost of higher education.

11. **Collaborate With Professionals From Industry and the Military**
    Similar to the previous strategy involving engineers as mentors, professionals from industry and the military often have a wealth of expertise in STEM. Allowing students to work with these individuals on class projects enhances students’ T&E education experience while also introducing industry and military personnel to the benefits of teaching. There are a number of highly successful T&E teachers who have transitioned into T&E education from a previous career in industry or the armed forces (Ritz, Berry, & Radcliffe, 1999). Companies and various branches of the military also offer ample scholarship opportunities for students interested in pursuing degrees in STEM-related fields.

12. **Collaborate With Career and Technical Education Programs**
    Although career and technical education (CTE) programs are separated from T&E education programs in most school systems, they can still serve as an excellent recruitment area. Students in these programs may often graduate with a technical certification and decide they want to pursue a bachelor’s degree. T&E education can be an easy transition for these students who possess expertise in a technical area and enjoy hands-on hobbies. Establishing a relationship with CTE teachers to collaborate on similar class projects (e.g., construction, manufacturing, transportation) can increase T&E students’ knowledge about a specific topic while also allowing CTE students to teach T&E concepts.

13. **Collaborate With STEM and Education Programs at Nearby Colleges**
    In the same vein as other collaborative efforts, working with nearby community colleges and four-year institutions that offer STEM and engineering programs can be valuable partnerships. They can allow local schools to collaborate with university programs that may have more expertise and funding to facilitate STEM activities. These partnerships also allow high school students to work with college students.
who serve as young role models for T&E fields. Students in these community college and university programs will gain a better understanding of what teaching T&E is like, and in turn may seek out opportunities to teach. Specifically at the community college level, T&E teachers should look to collaborate with Associate of Arts in Teaching (A.A.T.) programs. These students are interested in teaching and plan to transfer to a four-year institution. Showing A.A.T. students from various content areas how much fun T&E education is and where to earn a degree can help persuade them to pursue T&E education as a career.

14. Stay in Contact with Former Students
The final strategy suggests that T&E educators stay in contact with students who graduated and enrolled in STEM-related college programs such as engineering. Sometimes these students will discover that their major was not what they had expected and are seeking another career path that is similar in content. T&E teachers could encourage these students to enroll in a T&E education program.

Conclusion
Given the rapid rate at which the number of T&E education programs is declining, the number of qualified graduates to fill T&E education vacancies is limited. If T&E education programs cannot find a way to recruit more students, they are at risk of closure, and the field of T&E education may slowly become subsumed by other disciplines teaching engineering content and practices (e.g., science education, CTE). The strategies shared by Allen Androkites and Scott Didra reinforce the focus of this article—T&E teachers have the resources and potential to influence many students to become T&E educators, and they are the key to the future of T&E education!

This article only provided an overview of those strategies found to be successful. Teachers should share their personal recruitment stories with colleagues and state T&E supervisors to replicate successful models. Recruitment does not rest solely on the shoulders of practicing teachers. It should be approached as a collaborative effort among classroom teachers who serve as walking billboards for T&E education and university faculty members who prepare future T&E teachers. Together we can improve the declining enrollment trends of T&E teacher preparation programs.

References


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This is a refereed article.
Students learn better by doing.
At least that is what elementary and secondary science, technology, engineering, and mathematics teachers think. This is the fourth report discussing the Learn Better by Doing study. The first report (Round 1) (Moye, Dugger, & Starkweather, 2014a) introduced the study, defined “doing” in the context of this study, described why “doing” in the classroom is important, why there is a need for this study, and also provided selected findings from the first round of surveys. The second report (Moye, Dugger, & Starkweather, 2014b) identified the methods used and results of the first-round data. Round two (Moye, Dugger, & Starkweather, 2015) provided the number and percentages of responses and selected findings. This report presents the data found in rounds one, two, and three and provides information concerning the future of this four-round study.

The purpose of this study is to determine the extent to which U.S. public school students are doing hands-on activities in their classrooms. This study asks elementary and secondary (middle and high school) science, technology, engineering, and mathematics (STEM) teachers to respond to 13 statements concerning students “doing” in their classrooms. The first two statements are general in nature and are used for all grade levels. The remaining 11 statements are grade-level specific and based on Next Generation Science Standards (Achieve, 2013a; 2013b), Standards for Technological Literacy (ITEA/ITEEA, 2000/2002/2007), and Common Core State Standards for Mathematics (CCSSO, 2010). This report presents data collected from the first three of four rounds of the Learn Better by Doing study. Once the data from all four years are collected, the researchers will publish a final report, which will include the four rounds of data, implications of the results, and recommendations. Due to space limitations, the details concerning the methodology for this study are not described herein but can be found in Moye, Dugger, and Starkweather, 2014a and 2014b.

Findings
This round was open for teacher participation from July, 2015 until April 15, 2016. As in Rounds 1 and 2, teachers were asked to respond “Yes” or “No” to two general statements and 13 grade-level (elementary, middle, and high school) statements. The first general statement asked if teachers believe that students benefit from doing activities to support learning. The second statement asked teachers if they would assign their students more projects to do in class if they had the time and resources. A total of 1,050 eligible teachers responded to the two general statements. Of that number, 225 were elementary teachers, 270 secondary science, 298 sec-

*This research article is a result of an ITEEA/FTEE (Dugger/Gerrish endowment) research project.

by
Johnny Moye,
DTE, William E.
Dugger, Jr., DTE,
and Kendall N.
Starkweather,
DTE
learn better by doing study—third-year results

Table 1. General Statements, Number of “Yes” Responses/Total Responses, and Percentages of “Yes” Responses.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Elementary “Yes”</th>
<th>MS &amp; HS Science “Yes”</th>
<th>MS &amp; HS Technology and Engineering “Yes”</th>
<th>MS &amp; HS Math “Yes”</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I believe that students benefit from doing activities to support learning.</td>
<td>433/437 (99.1%)</td>
<td>296/296 (100%)</td>
<td>222/225 (98.7%)</td>
<td>253/254 (99.6%)</td>
</tr>
<tr>
<td>2. Given the time and resources, I would assign my students more projects to do in class.</td>
<td>422/437 (96.6%)</td>
<td>288/296 (97.3%)</td>
<td>221/223 (99.1%)</td>
<td>382/404 (94.6%)</td>
</tr>
</tbody>
</table>

Table 2. Rounds 1, 2, and 3 Elementary School Statements, Number of “Yes” Responses/Total Responses, and Percentage of “Yes” Responses.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3. …developed an object, tool, process or system that included several criteria for success and constraints on materials, time, or cost.</td>
<td>198/365 (54.2%)</td>
<td>133/243 (54.7%)</td>
<td>93/155 (60%)</td>
<td></td>
</tr>
<tr>
<td>4. …constructed an object using the design process.</td>
<td>196/365 (53.7%)</td>
<td>138/243 (56.8%)</td>
<td>104/155 (67%)</td>
<td></td>
</tr>
<tr>
<td>5. …designed and built a product or system.</td>
<td>174/365 (47.7%)</td>
<td>119/243 (49%)</td>
<td>94/155 (60.6%)</td>
<td></td>
</tr>
<tr>
<td>6. …controlled variables to conduct an investigation that produced data serving as evidence.</td>
<td>222/365 (60.8%)</td>
<td>149/243 (61.3%)</td>
<td>92/155 (59.4%)</td>
<td></td>
</tr>
<tr>
<td>7. …performed an activity to solve a design problem.</td>
<td>198/365 (54.2%)</td>
<td>145/243 (59.7%)</td>
<td>91/155 (58.7%)</td>
<td></td>
</tr>
<tr>
<td>8. …generated and compared multiple solutions to a design problem, based on the criteria and constraints of that problem.</td>
<td>153/365 (41.9%)</td>
<td>116/243 (47.7%)</td>
<td>69/155 (44.5%)</td>
<td></td>
</tr>
<tr>
<td>9. …built a model and then improved the design to better meet requirements.</td>
<td>170/356 (46.6%)</td>
<td>118/243 (48.6%)</td>
<td>84/155 (54.2%)</td>
<td></td>
</tr>
<tr>
<td>10. …tested and evaluated solutions for a design problem.</td>
<td>157/365 (43%)</td>
<td>114/243 (46.9%)</td>
<td>80/155 (51.6%)</td>
<td></td>
</tr>
<tr>
<td>11. …built and used a model to communicate their solutions to a problem.</td>
<td>162/365 (44.4%)</td>
<td>116/243 (47.7%)</td>
<td>84/155 (54.2%)</td>
<td></td>
</tr>
<tr>
<td>12. …built something designed to meet specific criteria and constraints.</td>
<td>217/365 (59.5%)</td>
<td>131/243 (53.9%)</td>
<td>106/155 (68.4%)</td>
<td></td>
</tr>
<tr>
<td>13. …used a computer program to model and simulate a solution to a problem.</td>
<td>80/365 (21.9%)</td>
<td>60/243 (24.7%)</td>
<td>35/155 (22.6%)</td>
<td></td>
</tr>
</tbody>
</table>

Total Yes Responses/Total Responses and Percentage of Doing in Courses

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>1927/4015 (48%)</td>
<td>1339/2673 (50.1%)</td>
<td>932/1705 (54.7%)</td>
<td></td>
</tr>
</tbody>
</table>
learn better by doing study—third-year results

Three hundred three middle school teachers responded to Statements 3 through 13: 93 science, 126 technology and engineering, and 84 mathematics teachers. Table 3 identifies middle school Statements 3 through 13, the number of teachers who replied “Yes,” the total number of responding teachers, and the percentage of teachers indicating “Yes” to each Statement. The last row of the Table contains the number of “Yes” responses/total responses and percentages of doing in courses. As with the elementary data, the researchers derived the percentages by adding the number of “Yes” responses in each column and dividing that number by the total number of responses in those columns.

Table 3. Rounds 1, 2, and 3 Middle School Statements, Number of “Yes” Responses/Total Responses, and Percentage of “Yes” Responses.

<table>
<thead>
<tr>
<th>Statement</th>
<th>MS Science</th>
<th>MS Tech. &amp; Engineering</th>
<th>MS Math</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. …developed a solution to be tested and then modified it on the basis of the test results.</td>
<td>94/133</td>
<td>61/83</td>
<td>62/93</td>
</tr>
<tr>
<td></td>
<td>70.7%</td>
<td>73.5%</td>
<td>66.7%</td>
</tr>
<tr>
<td>4. …created a tool or model to address an individual or societal need or want.</td>
<td>51/133</td>
<td>37/83</td>
<td>33/93</td>
</tr>
<tr>
<td></td>
<td>38.3%</td>
<td>44.6%</td>
<td>35.5%</td>
</tr>
<tr>
<td>5. …tested and evaluated a design in relation to pre-established requirements.</td>
<td>92/133</td>
<td>64/83</td>
<td>62/93</td>
</tr>
<tr>
<td></td>
<td>69.2%</td>
<td>77.1%</td>
<td>66.7%</td>
</tr>
<tr>
<td>6. …made a model to test for solutions to a problem.</td>
<td>85/133</td>
<td>65/83</td>
<td>52/93</td>
</tr>
<tr>
<td></td>
<td>63.9%</td>
<td>78.3%</td>
<td>55.9%</td>
</tr>
<tr>
<td>7. …completed an activity that demonstrated how humans use natural resources that have positive and negative short and long-term consequences.</td>
<td>71/133</td>
<td>47/83</td>
<td>39/93</td>
</tr>
<tr>
<td></td>
<td>53.4%</td>
<td>56.6%</td>
<td>41.9%</td>
</tr>
<tr>
<td>8. …created a model by applying criteria and constraints.</td>
<td>90/133</td>
<td>64/83</td>
<td>57/93</td>
</tr>
<tr>
<td></td>
<td>67.7%</td>
<td>77.1%</td>
<td>61.3%</td>
</tr>
<tr>
<td>9. …designed and used instruments to gather data.</td>
<td>92/133</td>
<td>57/83</td>
<td>54/93</td>
</tr>
<tr>
<td></td>
<td>69.2%</td>
<td>68.7%</td>
<td>58.1%</td>
</tr>
<tr>
<td>10. …analyzed and interpreted data to determine similarities and differences in findings.</td>
<td>120/133</td>
<td>79/83</td>
<td>81/93</td>
</tr>
<tr>
<td></td>
<td>90.2%</td>
<td>95.2%</td>
<td>87.1%</td>
</tr>
<tr>
<td>11. …solved a design problem by developing an object, tool, process, or system.</td>
<td>69/133</td>
<td>47/83</td>
<td>44/93</td>
</tr>
<tr>
<td></td>
<td>51.9%</td>
<td>56.6%</td>
<td>47.3%</td>
</tr>
<tr>
<td>12. …performed an experiment to solve a design problem.</td>
<td>88/133</td>
<td>60/83</td>
<td>43/93</td>
</tr>
<tr>
<td></td>
<td>66.2%</td>
<td>72.3%</td>
<td>46.2%</td>
</tr>
<tr>
<td>13. …identified the characteristics of a design that performed the best during a test process.</td>
<td>79/133</td>
<td>58/83</td>
<td>49/93</td>
</tr>
<tr>
<td></td>
<td>59.4%</td>
<td>69.9%</td>
<td>52.7%</td>
</tr>
<tr>
<td>Total Yes Responses/Total Responses, and Percentage of Doing in Courses</td>
<td>931/1463</td>
<td>639/913</td>
<td>576/1023</td>
</tr>
<tr>
<td></td>
<td>63.6%</td>
<td>70%</td>
<td>56.3%</td>
</tr>
</tbody>
</table>

The data reveals that middle school students are doing more hands-on activities in technology and engineering courses than in science and mathematics courses. This point becomes more evident when viewing the data as depicted in Figure 1.

Figure 1. Rounds 1, 2, and 3 Percentage of Doing in Middle School Content Areas.
At the high school level, 386 teachers responded, of which 130 were science, 129 technology and engineering, and 127 mathematics. Table 4 identifies high school Statements 3 through 13, the number of teachers who responded “Yes,” the total number of responding teachers, and the percentage of teachers indicating “Yes” to each statement. The last row of the table contains the number of “Yes” responses/total responses, and percentages of doing in courses. The researchers used the same method as with the elementary and middle school data to determine the percentage of doing at the high school level.

### Table 4. Rounds 1, 2, and 3 High School Statements, Number of “Yes” Responses/Total Responses, and Percentage of “Yes” Responses.

<table>
<thead>
<tr>
<th>Statement</th>
<th>HS Science</th>
<th>HS Tech. &amp; Engineering</th>
<th>HS Math</th>
</tr>
</thead>
<tbody>
<tr>
<td>My students have...</td>
<td>2014</td>
<td>2015</td>
<td>2016</td>
</tr>
<tr>
<td>3. …developed a solution to a complex real-world problem, based on scientific knowledge and student-generated sources of evidence.</td>
<td>111/220 50.5% 91/142 64.1% 77/130 59.2%</td>
<td>245/308 79.5% 269/325 82.8% 100/129 77.5%</td>
<td>68/151 45% 45/104 43.3% 61/127 48.0%</td>
</tr>
<tr>
<td>4. …built a model of something to simulate the interactions between systems such as energy, matter, or information flow.</td>
<td>124/220 56.4% 95/142 66.9% 78/130 60%</td>
<td>217/308 70.5% 226/325 69.5% 93/129 72.1%</td>
<td>34/151 22.5% 23/104 22.1% 23/126 18.3%</td>
</tr>
<tr>
<td>5. …created a presentation communicating the specifications and results of a design process used to meet a need.</td>
<td>90/220 40.9% 77/142 54.2% 76/130 58.5%</td>
<td>242/308 78.6% 257/325 79.1% 110/129 85.3%</td>
<td>52/151 34.4% 33/104 31.7% 39/126 31%</td>
</tr>
<tr>
<td>6. …built a model using specified criteria and constraints.</td>
<td>154/220 70% 106/142 74.6% 91/130 70%</td>
<td>285/308 92.5% 298/325 91.7% 118/129 91.5%</td>
<td>70/151 46.4% 47/104 45.2% 56/126 44.4%</td>
</tr>
<tr>
<td>7. …identified and applied criteria and constraints to develop a system or product.</td>
<td>94/220 42.7% 82/142 57.7% 68/130 52.3%</td>
<td>275/308 89.3% 283/325 87.1% 122/129 94.6%</td>
<td>54/151 35.8% 38/104 36.5% 47/126 37.3%</td>
</tr>
<tr>
<td>8. …performed research to determine criteria and constraints driven by a societal problem.</td>
<td>96/220 43.6% 63/142 44.4% 68/130 52.3%</td>
<td>184/308 59.7% 190/325 58.5% 79/129 61.2%</td>
<td>40/151 26.5% 22/104 21.2% 22/126 17.5%</td>
</tr>
<tr>
<td>9. …developed a solution to a major global challenge such as the need for improved health or supplies of clean water and food.</td>
<td>39/220 17.7% 31/142 21.8% 34/130 26.2%</td>
<td>80/308 26% 63/325 19.4% 34/129 26.4%</td>
<td>13/151 8.6% 3/104 2.9% 6/126 4.8%</td>
</tr>
<tr>
<td>10. …applied the design process to evaluate an existing design or to collect data.</td>
<td>105/220 47.7% 86/142 60.6% 76/130 58.5%</td>
<td>239/308 77.6% 256/325 78.8% 105/129 81.4%</td>
<td>50/151 33.1% 30/104 28.8% 38/126 30.2%</td>
</tr>
<tr>
<td>11. …built a prototype and checked it for quality and efficiency.</td>
<td>53/220 24.1% 49/142 34.5% 38/130 29.2%</td>
<td>247/308 80.2% 269/325 82.8% 110/129 85.3%</td>
<td>21/151 13.9% 17/104 16.3% 20/126 15.9%</td>
</tr>
<tr>
<td>12. …used computer simulations to predict the effects of a design solution.</td>
<td>54/220 24.5% 41/142 28.9% 37/130 28.5%</td>
<td>168/308 54.5% 188/325 57.8% 83/129 64.3%</td>
<td>35/151 23.2% 15/104 14.4% 20/126 15.9%</td>
</tr>
<tr>
<td>13. …evaluated a design solution by using conceptual, physical, or mathematical models to check for proper design.</td>
<td>44/220 26% 47/142 33.1% 38/130 29.2%</td>
<td>216/308 70.1% 223/325 68.6% 91/129 70.5%</td>
<td>42/151 27.8% 23/104 22.1% 26/126 22.2%</td>
</tr>
<tr>
<td>Total Yes Responses/Total Responses, and Percentage of Doing in Courses</td>
<td>964/2420 39.8% 768/1562 49.2% 681/1430 47.6%</td>
<td>2398/3388 70.8% 2522/3575 70.5%</td>
<td>1045/1419 73.6%</td>
</tr>
</tbody>
</table>
learn better by doing study—third-year results

As with middle school, high school technology and engineering students are more frequently doing hands-on activities than are science and mathematics students. Figure 2 provides a graphic illustration of how high school technology and engineering students are learning by doing substantially more than are science and mathematics students.

Determining the elementary and secondary percentage of doing is the focus of this study. Table 2 easily identifies the elementary percentage of doing, (2014 - 48%, 2015 - 50.1%, 2016 - 54.7%). In order to determine the secondary percentage of doing, the researchers combined the middle and high school data for each secondary level content area for each round/year. The combined percentage of doing in secondary science courses was 48.8%, in Round 1, 56.8% in Round 2, and 51.2% in this Round. The percentage of doing in technology and engineering courses was 73.6% in Round 1, 74.3% in Round 2, and 77.1% in this Round. As for students doing hands-on activities in mathematics courses, it was at 31.8% in Round 1, 29.5% in Round 2, and 31.2% in this Round. The combined secondary percentages bring to light a significant point—secondary technology and engineering students are learning by doing considerably more than are secondary science and mathematics students. Figure 3 shows the level of doing in secondary science, technology and engineering, and mathematics content areas in Rounds 1, 2, and 3.

Discussion

When the researchers designed this study, they chose to identify the results of each round by calculating the percentage of doing versus using another higher-order statistical tool. This decision was made to simplify the ability for teachers to answer “Yes” or “No” to the statements as well as make it easy for decision makers to understand the methodology used to determine the level (percentage) of doing occurring in K-12 science, technology, engineering, and mathematics courses.

More middle school science and mathematics teachers and more high school mathematics teachers responded in this Round (2016) than in Round 2 (2015), but did not reach the number of responses in Round 1 (2014). This is an interesting point because the researchers sent five times the number of emails in this Round (over 30,000) than were sent in Rounds 1 and 2. The reason could be school divisions’ use of spam programs to block unsolicited emails or emails from unrecognized addresses.

This round found that the vast majority of teachers feel that students benefit from doing activities to support learning, (elementary 98.7%, secondary science 100%, secondary technology and engineering 99.7%, and 100% of secondary mathematics teachers).

When asked if teachers would assign their students more projects to do in class if given the time and resources, they overwhelmingly indicated that they would. At the elementary level, 99.1% said “Yes,” 97.7% secondary science, 95.3% technology and engineering, and 96.9% mathematics teachers indicated “Yes.”

The results of the first two Statements indicate that classroom teachers feel that students learn better by doing.

The data show that for the third consecutive year, technology and engineering students are learning by doing more than are elementary and secondary science and mathematics students. When reviewing the three years of data, it shows that the lowest percentage of doing in secondary technology and engineering courses (73.6% in 2014) was almost 17 percentage points greater than the highest percentage of elementary or secondary science and mathematics content areas. The 2015 secondary science percentage (56.8%) was the percentage closest to the lowest technology and engineering percentage. This finding is very important. If students learn better by doing, as the vast majority of teachers suggest, then students who do not take technology and engineering courses are missing an opportunity to use hands-on activities to learn science and mathematics course content.

Education leaders should recognize that learning by doing is a valuable resource, and it is occurring more frequently in technology and engineering classrooms.
For the third consecutive year, elementary teachers reported a higher percentage of doing than in the previous year (2014 - 48%, 2015 - 50.1%, 2016 - 54.7%). The percentage of doing in Round 3 increased in 7 of the elementary 11 statements. There was a decrease in four statements, but that decrease was no greater than 3.2% in any of those statements. Although the elementary percentages have varied somewhat, they have remained relatively consistent during the three rounds.

The researchers used two instruments to collect secondary (middle school and high school) information. Teachers were asked to respond “Yes” or “No” to 11 grade-level statements. These statements are based on Standards for Technological Literacy (ITEA/ITEEA, 2000/2002/2007), Next Generation Science Standards (Achieve, 2013a; 2013b), and Common Core Standards for Mathematics (CCSSO, 2010). Teachers in all three content areas agree (to some degree) that their students were doing the same kinds of activities in their classrooms. The data show that technology and engineering students do the same types of standards-based projects and activities (more frequently) than do science and mathematics students. Putting this point into perspective, technology and engineering students perform hands-on activities requiring the use of science and mathematics concepts more frequently than do science and mathematics students in those classrooms. Education leaders should investigate how to use their technology and engineering programs to improve overall science and mathematics student achievement.

With the exception of middle and high school science, the overall percentage of doing remained relatively the same in each content area in each round. In 2014 the percentage of doing in secondary science courses was at 48.8%. That percentage increased 8 percent (to 56.8%) in 2015, but in the 2016 round it decreased to 51.2% (2.4% higher than the 2014 percentage). This study is not designed to determine why percentages may vary. Round 4 will provide data that will help determine the average level of doing in secondary science courses. It should be noted that it has been three years since the publication of Next Generation Science Standards (Achieve, 2013a; 2013b). One of the purposes of NGSS is to increase engineering practice (doing) in the science classroom. Implementation of NGSS could have an impact on the percentage of doing in science classes.

The purpose of this study is to determine the extent to which U.S. public school students are doing activities in their classrooms. When examining the data more closely, there are many other interesting points (findings). For example, as previously noted, the percentage of doing in elementary classes has increased in each of the three rounds. The data show that over half of the elementary students use a design process in some way to develop an object, tool, process, or system dealing with constraints on materials, time, and cost. They engage in activities to construct objects to solve problems designed to meet specific criteria and constraints. It appears that, implicitly or explicitly, more than half of elementary students have been exposed to an engineering design process. Students therefore should be able to use this process at the secondary education level. This is an important point. Standards for Technological Literacy states, “The design process is a purposeful method of planning practical solutions to problems” (ITEA/ITEEA, 2000/2002/2007, p. 94). Next Generation Science Standards encourages teachers to raise “engineering design to the same level as scientific inquiry in science classroom instruction” (Achieve, 2013a, p. xii). The Common Core State Standards for Mathematics document states, “The Standards of Mathematical Practice [or doing] describes varieties of expertise that mathematics educators at all levels should seek in their students” (CCSSO, 2010, p. 6). That practice is to include “problem solving, reasoning and proof, communication, representation, and connections” (CCSSO, 2016, p. 6). Secondary science and mathematics teachers expect their students to use some form of the engineering design process (e.g., doing or practice), but the data show they do not expect it as often as technology and engineering teachers do. The engineering design process may be new to science and mathematics teachers, but technology and engineering teachers have used this process as an instructional method—and their students have used it to perform hands-on activities to solve problems—for decades.

When comparing middle and high school data, it is interesting to find that the level (percent) of doing decreased from middle school to high school in each content area each year. With only one exception, technology and engineering showed a lower percentage of decrease than did either science or mathematics. In 2014 mathematics showed a 7.3% decrease, and technology and engineering a 7.5% decrease. As was previously noted, middle and high school technology and engineering students are doing more hands-on activities in their courses than are science and mathematics students. The data also reveals that the decrease of doing between middle and high school is not as extreme in technology and engineering programs when compared to science and mathematics programs. Many students become less interested while in high school (NRC-IM, 2004). Leaders should ask: Could there be a correlation between the amount of doing and student interest in school? Figure 4 provides an illustration of how the percentage of doing decreases between middle school (blue) and high school (red). The Figure also shows how doing in technology and engineering programs remains higher than in science and mathematics.

Presenting students with exciting and relevant activities is important to maintain their interest and participation. Research tells us that female students prefer studies and occupations that directly benefit society or individuals (Change the Equation, 2016; Eccles, 1994; NAE, 2008). In almost every incidence, statements concerning societal needs and wants received the lowest percentage of “Yes” responses at both the middle and high school levels.
When compared to the other nine Statements, middle school Statements #4, (my students have created a tool or model to address an individual or societal need or want) and #7 (my students have completed an activity that demonstrated how humans use natural resources that have positive and negative short- and long-term consequences) received the lowest percentage of “Yes” responses in science and mathematics. When high school science and mathematics teachers responded to Statement #9, (my students have developed a solution to a major global challenge such as the need for improved health or supplies of clean water and food), they also gave it the lowest number of “Yes” responses in each possible incidence.

Technology and engineering teachers also indicated “Yes” less frequently to these three statements in the three rounds. However, technology and engineering teachers indicated “Yes” to MS Statement #4 at a higher percentage than science and mathematics teachers nine out of nine times, and seven out of nine times for MS Statement #7. At the high school level, technology and engineering teachers also indicated “Yes” to HS Statement #9 more frequently than science and mathematics teachers, 8 out of 9 times. The point here is that technology and engineering students did more hands-on activities focusing on societal needs and wants than did science and mathematics students. The Vital Signs Report on the Condition of STEM Learning in the United States tells us, “Educators who harness TEL’s vision of literacy in technology and engineering may well attract many more girls to those fields” (Change the Equation, 2016, p. 9). If education leaders are interested in increasing female participation in STEM-related activities, continued education, and ultimately professions, those leaders should ensure that instruction and activities related to individual and societal areas are equally addressed in the classroom. Leaders should also note that technology and engineering students are performing these types of activities more frequently than are science and mathematics students. Figure 5 compares the percentage of students participating in hands-on activities relating to individual and societal needs and wants, as described in MS Statements 4 (orange), 7 (blue), and HS Statement 9 (green).

Summary

With the vast majority of teachers indicating that students learn better by doing, and the fact that students are doing more in technology and engineering courses, it stands to reason that technology and engineering courses are excellent resources to increase student achievement and better prepare them for continued education and the workplace.

This article identifies the results of the first three of four rounds of the Learn Better by Doing study. The researchers are currently conducting round four of this study. The survey instruments will be available until April 15, 2017. Using the same survey instruments and methods, the researchers will solicit input from as many elementary and secondary STEM teachers as possible. The results of the fourth round will be published in this journal. The researchers will also produce a Final Report containing the results of the four rounds, implications, and recommendations.

Elementary and secondary STEM teachers are encouraged to participate in this study, and can do so by following this link: www.iteea.org/Activities/2142/LearningbyDoingProject.aspx. Please feel free to contact the authors if there are any questions concerning this research study.
References

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Calling All STEM Teachers!
Are your public school students doing hands-on activities in your classroom? How many? How often?
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.
Using instant design challenges to introduce new concepts can lead to a more student-centered learning environment.

Introduction

Engineering design is a core component of technology and engineering education, and although not every student will become an engineer following high school, all students can profit from having engineering design experiences in high school (Apedoe, Reynolds, Ellefson, & Schunn, 2008; Denson & Lammi, 2014; Grubbs & Strimel, 2015; National Academy of Engineering and National Research Council, 2009; Wicklein, 2006). For example, a fundamental purpose of using engineering design is to help students develop critical thinking and team-working skills (Wicklein, 2006), specifically, engineering design that takes the form of an open-ended challenge that requires problem solving. Although there are many types of open-ended design challenges available to cultivate students’ cognitive ability, instant design challenges may be employed in technology and engineering education classrooms to contextualize learning for real-world problems. Furthermore, instant design challenges are a quick way of introducing new topics through simulated real-world problems. The purpose of this article is to illustrate how an instant design challenge can be employed in the context of transportation technology.

Instant Design Challenges: Meaningful and Relevant

In an instant design challenge, students are expected to utilize the engineering design process to solve a design problem in a condensed format. Most instant design challenges are formatted to be completed within a single class period—though it is questionable as to whether frequently employed challenges currently being implemented in technology and engineering education classrooms are being delivered in the most effective way possible. Moreover, have these instant design challenges effectively addressed the standards and objectives the instructor sought to meet? Lastly, how could these challenges be adapted to improve student-centered learning in the classroom? Typically, current instant design challenges may only be used to develop a basic set of problem-solving skills or to reinforce a principle that a student has already mastered. Furthermore, the design challenges could also be used to introduce a topic through a student-centered approach without much additional
effort in terms of intentional planning. For example, consider constructing a straw tower. The objective of the straw tower design challenge should not necessarily be to build the tallest tower possible using the given resources, but rather for students to use their observations to predictably determine how a specific structure can fail, or to see what shapes may best hold the most load. Subsequently, immersing students in an environment that allows them to observe and document the results of testing their prototype provides the first step of feedback necessary to develop their cognition. The second step is for instructors to provide descriptive feedback that informs their learning progression.

Instant Design Challenge: Float Your Boat

The instant design challenge that will be discussed here was created to challenge student thinking regarding the underlying causes of buoyancy. Some high school students have probably heard of buoyancy at some point in their lives, but do not know the factors that influence it. By the end of this activity, students will be able to explain which physical properties of a material or compound structure affect how an object floats.

In the Float Your Boat Challenge, teams of two to three students will design a watercraft capable of holding the most weight possible using only two feet of plastic wrap, ten drinking straws, and a foot of masking tape. It is best to use smaller weights, such as pennies or washers, to help students understand why objects float because it will assist them in understanding that both the surface area of the watercraft and the distribution of the weight relative to the center of gravity are key. At the end of the class period, students will collect and analyze data from their watercraft in order to better understand how characteristics such as surface area and weight affect buoyancy. The Float Your Boat Challenge can comfortably be done in a 90-minute class period or two 45-minute class periods. During the class period(s), students should complete the design process, including at least three tests of their prototype. The standards that align with this instant design challenge are listed in Table 2.

Table 1
Outline of class period. For two 45-minute class periods, end the first day after one official round of testing.

<table>
<thead>
<tr>
<th>Task</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Challenge Introduction</td>
<td>5 Minutes</td>
</tr>
<tr>
<td>Brainstorming</td>
<td>7 Minutes</td>
</tr>
<tr>
<td>Selecting the Best Design</td>
<td>5 Minutes</td>
</tr>
<tr>
<td>Construction/Testing</td>
<td>23 Minutes</td>
</tr>
<tr>
<td>Testing (Official Rounds)</td>
<td>20 Minutes</td>
</tr>
<tr>
<td>Analyze Data</td>
<td>8 Minutes</td>
</tr>
<tr>
<td>Think-Pair-Share</td>
<td>17 Minutes</td>
</tr>
</tbody>
</table>

Before the class period begins, the instructor should ensure that the student materials and testing tanks are ready to go. For the testing tanks, it is recommended to use any clear plastic container that is at least one-foot square. A larger container works best so the watercraft does not accidentally bump the side of the tank. Make graduation marks on the side of the container in sixteenths of an inch increments and fill up the container with at least 3 to 4 inches of water. An easy way to distribute materials to students is to place the straws in a plastic zipper bag. Next, precut the tape and attach it to the outside of the bag. Students will be able to easily remove the tape from the bag, and this will speed up the process of distributing materials to a large number of groups.

The first step in any good engineering design challenge should be the same regardless of whether the task is to build a paper bridge or to develop the next iteration of the Falcon 9 Rocket. No matter how small the challenge, always start by having students brainstorm several different ideas on how they plan to approach...
the challenge and select their best idea before receiving any materials. During the concept generation phase of the design process some students will crank out a few ideas in a matter of minutes, and others will slowly consider solutions. To help all students stay on track, one approach is to have a set amount of time for brainstorming instead of a minimum number of ideas to develop. Remind students that the brainstorming phase is not the time to be critical of each other’s ideas, but rather, to try to come up with many potential solutions as quickly as possible. As an educator, encourage students to think outside the box, as often these ideas can lead to the best solutions.

Now it is time for the most hands-on part of the design process, creating a prototype. Give students about twenty-three minutes to build and test their designs. During this time give students the opportunity to test their designs and make sure they are watertight. Due to the properties of the plastic wrap once it becomes wet, it may become necessary for some groups to replace their plastic wrap if major design modifications are necessary. Students should not be allowed to trade in any other materials except for the plastic wrap. Not allowing students to trade in materials makes them plan out the design more thoughtfully and forces them to follow the design process to ensure that they will have enough materials for the prototype.

Now that each team has a prototype, they should begin testing their designs and recording the data in their design notebooks. They should perform both a quantitative and qualitative analysis of their watercraft for each of the three trial runs. In any STEM-related field, it is good practice to have multiple data points in an experiment in case one of the trial runs is an anomaly and skews the data. From an engineering standpoint, it is important to show that the prototype can effectively and consistently meet the criteria set forth in the design statement. Data that should be recorded in the student’s engineering design journal is listed in Table 3.

As students are recording the data in their own journals, a master list of data should be written in the front of the classroom; this can be done by hand on the chalkboard or by using an Excel-like program. This will allow students to see how different designs produce different results and come to their own conclusion about what factors influence the watercraft’s ability to float.

Once all of the watercraft have been tested, give each group a few minutes to make sure they all have the same data written down in their design journals. As students begin analyzing the raw data, have students use some guiding questions in order to narrow their search on how the quantitative and qualitative data points are related to each other. Some examples of guiding questions can be found in Table 4.

Table 3
Topics for Data Analysis

<table>
<thead>
<tr>
<th>Data Collected</th>
<th>Type of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Area of Boat Bottom</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Number of Washers Held</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Initial Height of Water</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Final Height of Water</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Height of Boat</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Volume of Boat</td>
<td>Quantitative</td>
</tr>
<tr>
<td>Describe the placement of the washers in the boat.</td>
<td>Qualitative</td>
</tr>
<tr>
<td>How did the boat start to sink/take on water?</td>
<td>Qualitative</td>
</tr>
<tr>
<td>What is the geometric shape of the bottom of your boat?</td>
<td>Qualitative</td>
</tr>
</tbody>
</table>

Table 4
Sample Guiding Questions

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which variables have a proportional relationship?</td>
</tr>
<tr>
<td>Which variables have an inversely proportional relationship?</td>
</tr>
<tr>
<td>Are there any variables that do not have a correlation?</td>
</tr>
<tr>
<td>Why do you think the water level rises when more weight is added to the boat?</td>
</tr>
</tbody>
</table>

It is important for students to have time to analyze the information on their own before sharing with their group or the rest of the class. Using this Think-Pair-Share method ensures that all students have time to develop their own ideas before conforming to “grouphink” and destroying some potentially good ideas. Students should be encouraged to journal their ideas so they have something written down before they share and their idea does not get influenced by groupthink. After approximately five minutes, allow students to return to their groups to discuss their ideas.
Drawing a Conclusion

By the time students get to group discussion they should see some basic patterns arising from the data they are analyzing. For example, by looking at the class set of data, students should see a proportional pattern between the volume of the boat and the amount of weight that the watercraft can hold. Some groups might only look at the surface area of the hull versus the weight, but that is not the entire relationship. Ultimately, the amount of weight a boat can carry is proportional to the amount of water it can displace, meaning that the weight of the water displaced is equal to the total weight in the boat. The amount of water displaced can be calculated by multiplying the height of the water rise by the surface area of the water. An example of how to calculate the surface area of the water can be found in Figure 1.

If a student’s group is convinced that only the surface area matters, have them revisit and build two watercraft with identical hulls. Have them add sides to one of the watercraft and leave the other as a flat raft, and have the students discuss the outcome of the secondary experiment. The students should notice that the watercraft with sides was able to displace more water and therefore hold more weight.

Students may also see a small pattern where a few boats with a large volume could not hold a lot of weight. This is due to the placement of the weight relative to the watercraft’s center of gravity. The offset of the weight will cause a rotation to occur near the center of gravity—where one side of the watercraft will dip into the water, and the other side will begin to rise. This will ultimately cause water to start flowing into the boat before it has displaced an amount of water equal to the volume of the watercraft—making the boat less efficient than some of the other designs. This scenario can also be considered an outlier in the data set. If the students ask questions about whether or not the placement of the weight matters, have them attempt to balance a pencil on one finger. Then have them think about where they could add a weight to the pencil without it falling off. Students should conclude that placing the weight in the center above their finger will not cause the pencil to fall. This is because placing the weight in this particular location does not generate a rotational force and keeps the pencil level. Ultimately the top of the watercraft needs to remain level relative to the water in order
resources in technology and engineering

Conclusion

Although design challenges are used in a multitude of situations, using instant design challenges to introduce new concepts can lead to a more student-centered learning environment. Additionally, when implemented thoughtfully, specific concepts and experiences can be drawn out for students to encounter. Although this approach may take more time implementing both in and out of the classroom, it will ultimately lead to an increase in student understanding and make the class more engaging. Allowing the students to think critically with guided questions is the key to success in using instant design challenges to introduce topics using a more-student centered approach (rather than having a teacher-led lesson). As current design challenges—used as anticipatory sets or to deliver core content—are implemented in the classroom, they can easily be reconfigured to intentionally immerse students in an authentic learning experience.

References


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Many youth do not pursue engineering because they do not see how it connects to their lives and interests. Concerned about this problem, the National Research Council (2012) suggested ways that teachers can make engineering more relevant and accessible to youth who have not traditionally pursued careers in this field. According to the National Research Council, children develop their own ideas about how the world works based on their personal experiences, and "by listening to and taking these ideas seriously, educators can build on what children already know and can do" (pp. 24-25). One way that technology teachers can connect students' interests and experiences to engineering is through drawing from their funds of knowledge.

Funds of knowledge include knowledge, skills, and practices that students develop through interactions with family members, neighbors, and peers (Moll, Amanti, Neff, & González, 1992). Doing chores around the house, visiting relatives in other countries, or holding jobs all provide students with useful knowledge and skills. Technology and engineering (TE) teachers who take advantage of these extracurricular funds of knowledge will find that their students already have valuable experiences that are relevant to the curricula they teach.

Although all students can benefit when teachers draw from their everyday experiences, this instructional approach is especially beneficial for youth who have been historically underrepresented in engineering. In fact, several studies (e.g., Barton & Tan, 2009; Civil, 2002; Grimberg & Gummer, 2013) have shown that when science and mathematics teachers draw from the funds of knowledge of African American, Latino/a, and Native American students, they can make the subject matter relevant to students' lives and increase their interest in the field.

At its core, engineering is about making a difference in the quality of people's lives.
youth, their students become invested in learning and are more likely to envision themselves in STEM fields.

What background experiences and practices do youth hold that are relevant to engineering, and how can TE teachers tap into them? To answer this question, the authors followed groups of youth as they selected problems in their local communities and solved them through engineering. The youth drew from their funds of knowledge to solve these problems, which ranged from improving local playgrounds to cat-nabbing devices. After identifying different categories of engineering-related funds of knowledge, the authors then developed and implemented instructional approaches designed to tap into students’ interests, skills, and backgrounds. In this article, the authors describe several categories of funds of knowledge and suggest ways that TE teachers might incorporate them into their teaching.

Funds of Knowledge Relevant to Engineering

Many youth hold engineering-related funds of knowledge in the following four categories: household management, workplace skills, recreation, and transnational experiences (Wilson-Lopez, Mejia, Hasbún, & Kasun, in press). In other words, as youth improve their homes, solve problems at the workplace, play games with their friends, and maintain ties with family members in other countries, they often simultaneously learn practices and develop bodies of knowledge that are relevant to the competencies outlined in Standards for Technological Literacy (ITEA/ITEEA, 2000/2002/2007). (See table at right.) In this section, the authors describe how the youth in their study learned different engineering-related practices in the context of their everyday lives. It should be noted that these youth were all from underrepresented groups in engineering, such as youth of color from working-class backgrounds. In this article, the authors describe several categories of funds of knowledge and suggest ways that TE teachers might incorporate them into their teaching.

Household Management

Whether youth live in a crowded apartment in an urban area and need to maximize their living space, or whether they live on a farm and need to minimize soil erosion—most face problems in their households and environs that can be solved through the creation or improvement of devices, systems, and processes. Many youth have worked with their parents, guardians, or older siblings to identify and solve these problems (Wilson-Lopez et al.; Moll et al., 1992). They often help their parents improve or construct items in their yards, such as treehouses, sheds, and enclosures for animals. They also fix a variety of broken technologies, ranging from cars to video game consoles. Through these experiences, youth develop skills and lines of reasoning that can serve as useful resources for learning formal engineering principles.

### Table Connecting Funds of Knowledge to ITEEA Standards.

<table>
<thead>
<tr>
<th>Fund of Knowledge</th>
<th>Examples of Relevant STL Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household Maintenance</td>
<td>Standard 2-Z. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste. Standard 12-M. Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.</td>
</tr>
<tr>
<td>Workplace Skills</td>
<td>Standard 1-M. Most development of technologies these days is driven by profit motive and the market. Standard 9-L. The process of engineering design takes into account a number of factors (safety, reliability, economic, quality control, environmental concerns, maintenance and repair, and human factors engineering).</td>
</tr>
<tr>
<td>Recreation</td>
<td>Standard 13-K. Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and the environment. Standard 9-K. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.</td>
</tr>
<tr>
<td>Transnationalism</td>
<td>Standard 2-X. Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems. Standard 6-H. Different cultures develop their own technologies to satisfy their individual and shared needs, wants, and values.</td>
</tr>
</tbody>
</table>
Consider Kallie, a teen who worked with her father to identify the source of the water puddles beside their toilet. They considered whether the toilet was "sweating" due to condensation, whether the wax seal under the toilet had failed, whether a supply tube was loose, and more. Kallie helped her father use testing and observation to identify the source of the leak and fix it with tools. As suggested by this example, Kallie's father apprenticed her through the process of diagnosing a system that was malfunctioning. He also showed her how to use tools and knowledge—such as knowledge of what causes condensation or the knowledge of the properties of materials—to repair the system. As indicated by the table on the previous page, these skills are relevant to ITEEA's STL standards (e.g., Standard 12-M).

As a second example, consider Diego, a teen with two brothers who had degenerative muscular diseases and needed a shower chair to enter and exit the bathtub. His family, however, could not afford one that has a "nice head rest and everything. Shower chairs are so expensive, and a lot of Medicaid programs don't pay for them anymore." Other youth agreed with Diego that families with chronically ill members often spend a good deal of income on medical care, and consequently it was an ethical imperative to provide them with inexpensive solutions. Diego's group sought to address this problem by designing and constructing a shower chair headrest that could be attached to existing shower chairs. They prioritized low cost over aesthetic appearance when selecting materials. As suggested by this example, their experiences with managing disabilities and family budgets helped them to develop criteria by which they weighed trade-offs between competing values (low cost and aesthetics) as they decided which value was the most important to them (e.g., Standard 2-Z).

Workplace

Nationally, about 30% of teenagers hold jobs during the summer, while a smaller percentage hold part-time jobs during the school year (Cohen & Lieber, 2015). Even when working entry-level jobs, young people develop bodies of knowledge and skills that are relevant to engineering, such as learning how to use a variety of technical tools to solve problems, learning the processes by which employers maximize efficiency and profit, and participating in formal safety and quality-control measures. Workplace experiences therefore are a potentially useful fund of knowledge that can be connected to engineering standards.

Consider Paolo and Miguel, two youth who worked at a dairy farm where their employer’s primary goal was decreasing the bacteria count in cows’ milk in order to earn more money from their buyers. They noted that ideal but expensive solutions, such as frequently testing the cows for bacterial infections, would cut into the employer’s profit margins, so they helped their employers to develop inexpensive solutions, such as training new employees to wash manure off of their gloves before milking cows and routinely washing the parts of the milking equipment that came into contact with the cows. These solutions had to be balanced with safety measures, a lesson that Paulo learned firsthand when he tried to clean the machines with “acid…and my eyes were just burned really bad.” In other words, from their experiences working on the farm, the youth learned that designing a solution to their employer’s problem required them to rigorously account for a number of factors, such as cost, safety, and maintenance of machinery (e.g., Standards 1-M and 9-L).

Recreation

Although youth participate in a variety of recreational activities, digital technologies have become a ubiquitous source of recreation in the U.S. According to the Kaiser Foundation, adolescents spend more than 7.5 hours per day consuming digital media. Over three quarters of teenagers now have mobile devices. Many popular apps and video games engage youth in practices that are relevant to engineering, such as testing a variety of prototypes. Consider Mark, one youth who played with apps on his tablet that allowed him to design and test elaborate electrical circuits, while Laura and Eden used apps to construct bridges and test whether cars could safely drive across them. Similarly, Tim liked to use his tablet to design apple carts and determine whether they could prevent apples from bouncing out while moving across rocky terrains. These examples suggest that recreational apps can provide students with practice in redesigning models based on feedback from a variety of physical tests (e.g., Standard 9-K).

Many apps also provide youth with practice in systems thinking as they analyze trends from different sources of data and use them to draw conclusions about the effects of their design decisions. Consider Manuel and Sally, two teens who regularly played video games in which they built cities. These games required them to make decisions regarding where to install different types of businesses and what materials their structures should be made from. They received different types of feedback on their design decisions, such as data related to pollution levels, health levels, population levels, rate of deterioration, and general wealth of their city. The youth then analyzed their design decisions based on these large-scale data trends and redesigned their cities. In this way, video games provided them with practice in analyzing trends and determining how different aspects of their design affected society and the environment (e.g., Standard 13-K).

Transnationalism

About one in ten people in the U.S. are immigrants (CQ Press, 2015), many of whom maintain close ties with the countries in which they or their parents were born. The term “transnationalism” is used to describe individuals and families whose daily lives are influenced by the practices and cultures of multiple nations.
Transnational families often communicate with relatives in other countries through social media, and they exchange information as well as economic resources and goods (e.g., medicines). Transnational youth possess funds of knowledge that help them meet national standards, such as experience with how different cultures have developed their own unique technologies to satisfy human needs. They have also learned that different social, environmental, and technological systems influence the technologies that are accessible within those systems.

Consider Pamela and Veronica, two youth who sought to bring safe drinking water to their extended families and other people in rural regions of Honduras. They considered possible methods for accomplishing this goal, such as improving the existing water infrastructure that had been damaged by a hurricane. However, they asserted that corrupt officials had pocketed funds designated for infrastructure repair. They did not want to use local rivers as water sources because people often dumped waste in them. After considering these factors, they decided to design a roof-based catchment system, a solution that was feasible because it rained frequently in Honduras. As suggested by this example, Pamela and Veronica’s experience with living in Honduras taught them that their solution needed to account for existing social factors (e.g., political corruption), environmental factors (e.g., pollution in rivers and level of rainfall), and existing technological systems (e.g., damaged water infrastructure) (e.g., Standards 2-X and 6-H).

TE teachers can distribute this inventory to students at the beginning of the year in order to discover the types of engineering-related knowledge that their students already possess. The inventory includes responses we have received from students in the past.

Questions for Inventory
Engineers make a world of difference, improving the quality of everyday life for people in our families, our communities, and our world. What problems have you seen in your everyday life that could be solved through engineering? Have you developed solutions to these problems? The purpose of this inventory is to begin to identify experiences and skills you already have that relate to engineering.

Household and Community
(1) What problems have you seen in your homes or communities that could be solved through engineering? What ideas do you have for solving these problems?
When it snows a lot, the buses are usually late to school. I’ve thought about putting heating wires on the roads used for the bus route, or else making a new bus schedule to make sure everybody can arrive on time.
(2) Have you ever built, fixed, improved, or remodeled something in your house, yard, or neighborhood? If so, please briefly describe what you did.
My chickens were jumping out of their coop, so I used materials around my house to make and install a roof. I had to measure the chicken coop to make sure the roof was the right size, and I had to choose a material that would not hurt the chickens if they jumped up.

Workplace
(3) Do you hold a job, or have you ever helped your family members with their jobs? Please describe a typical day in the workplace for you or for a family member.
I paint houses with my dad. We first have to give an estimate by thinking up how much primer and paint we are going to use. My dad doesn’t want to use too much, or the price will be too expensive, but he can’t have too little or he won’t have enough. We paint the walls so that it takes the least amount of time and so that the primer has enough time to dry before we put on the paint.
(4) What problems have you or your family members solved as part of your jobs?
When we have a long line at our restaurant, we have to find ways to make sure the customers get their food quickly. We split up the work so that different people do different jobs.

Recreation
(5) What do you like to do in your spare time outside of school?
I volunteer at a retirement home for the elderly.
(6) What problems do you face when you are doing these things in your spare time?
A lot of the old people are sick, and we have to keep one person from infecting the other people who live there.
(7) Do you play any apps or video games that are related to engineering? If so, please describe how you play this game.
I play Bridge Constructor where you have to design bridges and see how much weight they will hold. I also play with a design app where I make clothes. A client provides feedback on the clothes, and I redesign them based on the client’s feedback.

International Experience
(8) What problems have you seen or read about in another country that could be solved through engineering?
My uncle lives in Honduras. The water pipes there were broken after Hurricane Mitch and a lot of people do not have safe drinking water.
Connecting Funds of Knowledge to Engineering

To improve student outcomes, TE teachers can tap into students’ funds of knowledge such as those described above. To accomplish this goal, they can first administer an inventory to their students at the beginning of the school year to identify some of the relevant experiences and skills held by their students. (See an example of a completed inventory on the previous page.) Because many students possess engineering-related funds of knowledge but are not aware of them, the teacher may first need to provide a few model answers to these questions, such as the examples provided above. As TE teachers actively seek to become more familiar with the communities in which they teach, they can include examples that are more relevant to their particular communities.

This inventory can be used in several different ways. If the results indicate that most students in the class face a common problem, then teachers may consider selecting that problem as the basis for a whole-class design challenge. For instance, most of the youth in the authors’ study owned outdoor animals that were in danger of freezing during the winters, and they had worked with their parents to modify existing animal enclosures. TE teachers could tap into those experiences by asking their students to improve an existing doghouse so that it could keep small dogs warm. The class would develop criteria and constraints needed for the design as they specified available materials and methods for measuring a successful outcome.

Even if TE teachers do not use the inventory as the basis for a design challenge, they may use the results from the inventory to solicit students’ expertise in classroom discussions throughout the school year. For instance, when teaching about how people in different regions of the world develop diverse solutions to similar problems, the teacher could ask students with transnational ties to share their experiences with others with countries. In this way, TE teachers can validate the bodies of knowledge and skills that students have developed in out-of-school settings. Students often become more excited about learning when they are positioned as experts about content, rather than simply as recipients of content. Drawing from students’ funds of knowledge in the classroom is one way to place students in the position of expert and to build on their existing knowledge.

Example of Classroom Instruction

The following scenario will demonstrate how the authors drew from students’ background experiences in their own classroom instruction. One author worked with middle school students whose parents were largely immigrant farm workers. Many of these youth had helped their parents at their workplace from a young age, and they or their parents had received injuries, including scratches from handling animals, cuts from machinery, and back pain from heavy lifting or falling to the ground.

As in most TE classrooms, these students were required to pass a test on lab safety before they were allowed to begin working in the lab. To introduce lab safety, the authors invited students to share experiences with injuries in the workplace, and they wrote a list on the whiteboard that outlined injuries in different categories. The authors then introduced the work of safety engineers, whose job is to design procedures and systems that keep people safe in the workplace and elsewhere. Acting as safety engineers, students then analyzed photographs of the TE lab that had been staged to highlight potential problems with lab safety. The students used the categories on the board to write a list of safety rules and procedures that they should follow in order to avoid injuries in the classroom lab. For instance, after viewing a photograph of an electric cord strewn across the floor of the lab, the class agreed that “inform your teacher of possible items on the floor that you could trip or slip on” was a rule that would help to prevent injuries in the “falling category.” After viewing a photograph of a person cutting wood without safety goggles, the class agreed that “wear protective gear” would help to avoid injuries in the “scratches category.”

Through drawing connections between safety engineering and their own familial experiences, the students discovered one way that engineering can make “a world of difference” (National Academy of Engineering, 2008, p. 8) through protecting themselves and the people they loved. Although this instructional example connected lab safety to workplace funds of knowledge, TE teachers can draw from students’ other funds of knowledge as well to highlight the relevance and importance of engineering to all aspects of daily life.

Conclusion

Engineering is not just about making cool gadgets or applying science and mathematics to problems. At its core, engineering is about making a difference in the quality of people’s lives. According to the National Academy of Engineering (2008), when teachers can powerfully communicate that message, more students will pursue engineering as a career. By rigorously incorporating students’ funds of knowledge, TE teachers show students that engineering is relevant to their everyday lives and that engineering can be used to solve problems and make a difference in the world around them.

References


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This is a refereed article.
Welcome to the inaugural article of Safety Spotlight, a unique column where specialists discuss critical STEM education safety issues. This first article addresses a topic that has received much attention over the past few years, since 3D printing technology has rapidly grown in popularity. As with many new technologies, there are unforeseen safety hazards that emerge over time. With 3D printers becoming more common in STEM education laboratories and makerspaces, researchers have begun investigating how hazardous 3D printing can be to the health of students and teachers.

What are Ultrafine Particles?

Health concerns from 3D printing were first documented by Stephens, Azimi, Orch, and Ramos (2013) who found that commercially available 3D printers were producing hazardous levels of ultrafine particles (UFPs) and volatile organic compounds (VOCs) when plastic materials were melted through the extruder. UFPs are particles less than 100 nanometers in diameter. When inhaled, UFPs can reach the brain or enter the human blood system in less than one minute. Once in the blood stream, filtering organs such as the liver and spleen are the most vulnerable. Common diseases associated with absorption of UFPs include bronchitis, tracheitis, asthma, and some forms of cancer (Merlo & Mazzoni, 2015). The inhalation of UFPs has been compared to the detrimental effects of smoking. More recent studies have revealed additional information about the hazards of UFPs emitted from 3D printing.

Recent Research Findings

Merlo and Mazzoni (2015) provided a thorough review of research examining the health risks associated with 3D printing. They presented the Stephens et al. (2013) finding that printing with PLA plastics produced a UFP concentration of 3 to 30 times less than using ABS plastics. PLA is...
a biodegradable plastic derived from plant-based resources like cornstarch and sugarcane, while ABS requires a higher melting point because it is made from oil-based resources. In 2012, Stratasys, a popular 3D printer manufacturer, hired an independent lab to conduct extensive air quality studies on its printers. The lab found that in all instances, chemical emissions were extremely low, and in most cases were less than 1% of the exposure limits specified by OSHA. Azimi et al. (2016) later discovered: “Results from a screening analysis of potential exposure to these products in a typical small office environment suggest caution should be used when operating many of the printer and filament combinations in poorly ventilated spaces or without the aid of combined gas and particle filtration systems” (p. 1267). More recently Steinle (2016) found that when 3D printing occurred in a large, well-ventilated room, UFP emission rates were considerably lower than other common indoor aerosol activities such as cooking or burning candles.

Recommendations for Schools and Teachers

The latest research findings would suggest the following recommendations for a safer learning/working environment:

1. Share the references cited in this article with the safety compliance officer, facilities director, and administrators/supervisors in your school system. Request that they conduct an air-quality analysis of your lab. This is to determine if your current air-filtration system meets the appropriate federal, state, and/or locally mandated air-changes-per-hour (ACH) rate for the equipment being used and activities being performed. This may be achievable with the proper size electrostatic air filter(s). Bear in mind a greater air-changes-per-hour rate is required for spaces where occupants are exposed to carcinogens and other chemical or particle hazards such as sawdust, spray paint, etc.

2. Ensure that gas and particle air-filtration systems (e.g., electrostatic air filter) in your lab are always turned on and functioning properly when 3D printers are in operation.

3. Operating 3D printers in exhaust ventilation fume hoods or spray booths is a safer means of prudently avoiding exposure to potentially harmful UFPs and VOCs.

4. Use PLA instead of ABS material for 3D printing, since it has been found to emit safer UFP concentrations.

5. Continue to follow the emerging research released on UFPs and 3D printing by periodically conducting internet searches. Share the latest findings with your school system’s safety compliance officer, OSHA specialist, and administrators/supervisors.

Conclusion

This safety issue is difficult to diagnose at the present time due to the limited research currently available. However, based on the most recent studies, the authors do not believe that schools and teachers should be overly concerned about operating a 3D printer in their laboratory if it is using PLA material and is in a facility with a room-change ventilation rate of at least 3 volumes of the room per hour. Newer, enclosed style 3D printers often feature a built in filter for UFPs; however, it is better professional practice that all 3D printers only be minimally operated in adequately ventilated rooms. At the present time, the more prudent approach is to operate 3D printers in fume hoods or spray booths. Teachers, administrators/supervisors, and school systems in general are encouraged to keep an eye on emerging studies that will continue to reveal more about the potential health risks associated with this technology.

References


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Ken Roy, Ph.D. is the chief science safety compliance adviser for the National Science Teachers Association (NSTA) and safety compliance officer for the National Science Education Leadership Association (NSELA). He also serves as Director of Environmental Health & Chemical Safety for the Glastonbury Public Schools (CT). Dr. Roy can be reached at safesci@sbcglobal.net.

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 Premise

Young folks enjoy creating and playing games, so why not challenge them to create games in the classroom, working in teams with 3-4 students per team. This takes into account the need to infuse more math into student activities.

It’s been said that one never becomes quite as intimate with a subject until one is asked to teach it. Combine this with the old, one-room-schoolhouse days when both teachers and older students, together, helped teach the lower classes, and we have a nice basis on which to launch this design challenge. Here it is: your upper middle school students are to design an educational math card game for use in the lower grades.
Planning

Any design activity begins with an excellent evaluation of how the design will proceed—and that begins with understanding why the design is needed in the first place. How will each student team determine what math concept they will try to design their card game to address?

How can the teams appreciate which math concepts need attention by lower grades? Should it be the classic concerns like fractions, division, and geometry? Could it be something else? Some data collection is needed here:

- Survey lower-grade students to determine which math topics are difficult for them.
- Consult the math teachers in your school in order to gain perspective.
- Research on the internet.
- Consult other sources for guidance.
- Find out what kinds of math games are on the market today, available from educational publishers.

Process

Once your student teams have determined which specific math topic will be addressed, students are ready to get down to business, developing the strategies the game will employ. How will the game provide experiences to improve student learning?

- What kinds of cards will be used?
- How many cards will each player receive; and what is the total number of cards to be used?
- How might the cards be illustrated?
- Will dice be used to instill a chance component?
- Will special playing cards also be used as a chance element?
- Design the total game, cards, and other components.

If possible, collect some samples of math card games to be studied by the teams to examine how such games are designed, constructed, and rules written.

Teams must make sure the game being considered is not like something already on the market.

Give the game a catchy title or slogan, ideally something that strongly relates to the math topic addressed!

Important Considerations

An educational game can only be enjoyed if the rules of the game are clear and concise. Students should include illustrative drawings and diagrams to aid players in understanding how game play progresses.

Teachers:

- Here is an opportunity to integrate the language arts into this design challenge.
  - Good writing skills are extremely important in the business world, as they are in launching new products like this card game.
- Be tough on the clarity of team game instructions. They must make sense to someone who has never seen or played this game before—especially any special card-playing instructions.
- Play the games of each team to make sure the instructions are very clear.

Teams also should play each other’s games to add their comments and perspectives; and of course, the younger students for whom the games are designed should also play the games and comment upon them, similarly to how new products are test-marketed before going into full production and sale.

Further challenge your student teams to make the card game adaptable to classroom play involving the entire class. How might this work so all students can play?

Finally, challenge the teams to discuss how their game design might be adaptable for computer, smartphone, or tablet play.

Have fun, and work that math component into your class challenges!
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