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[www.iteea.org/Application_To_Present_2021.aspx](http://www.iteea.org/Application_To_Present_2021.aspx)
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On the cover: TEECA teams compete at ITEEA’s 82nd Annual Conference in Baltimore, MD.
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Educator Resources From ITEEA During COVID-19

ITEEA has been compiling at-home resources since mid-March to support educators and students who are attempting to continue teaching and learning. New resources are being added regularly. ITEEA has also added the ability for educators to add links, photos, documents, and YouTube videos. Browse the library—and add your ideas—today at [www.iteea.org/covid.aspx](http://www.iteea.org/covid.aspx).

2020 REACH Challenge

ITEEA's REACH Challenge registration is now open! The registration fee includes instant access to the REACH Challenge Toolkit, a valuable set of activities, lesson plans, and slide presentations that are designed to teach students about User-Centered Design, Adaptive and Assistive Technology, Empathy, Prototyping, Intellectual Property, and more. Teams will also have help finding a User-Expert, as well as the ability to submit the team's project for awards from ITEEA. Each team can have up to 10 students, and a teacher can be the TEAM LEAD over multiple teams. Learn more/register today at [www.iteea.org/REACH.aspx](http://www.iteea.org/REACH.aspx).

2019 winners are listed on page 37.
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TECHNOLOGY AND ENGINEERING TEACHER
ISSN: 2158-0502, is published eight times a year (September through June, with combined December/January and May/June issues) by the International Technology and Engineering Educators Association, 1914 Association Drive, Suite 201, Reston, VA 20191. Subscriptions are included in member dues. U.S. Library and nonmember subscriptions are $80; $110 outside the U.S. Single copies are $10 for members; $11 for nonmembers, plus shipping and handling.

Technology and Engineering Teacher is listed in the Educational Index and the Current Index to Journal in Education. Volumes are available on Microfiche from University Microfilm, P.O. Box 1346, Ann Arbor, MI 48106.

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ITEEA Publications Department 703-860-2100 membership.sales@iteea.org

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White House OSTP Leads Effort to Increase Access to Online Education Resources

Recently, the technology industry announced the launch of TechforLearners.org, a new resource for educators, administrators, and public officials who are turning to online learning as coronavirus response disrupts the school year.

TechforLearners.org is a searchable online database of education technology tools that facilitate online classrooms and teaching, allowing educators to search for free and discounted tools and services by grade level, product type, and subject matter. The site, coordinated by the Software & Information Industry Association (SIIA), will be continually updated and will soon include additional resources geared towards parents and students.

“Teachers and educators across the Nation will be relying on technology now more than ever. During this unprecedented time, the Trump Administration is committed to ensuring America’s educators and families have the technology tools to bring classrooms online. We are grateful to the technology and education leaders who jumped into action to launch this important resource,” said U.S. Chief Technology Officer Michael Kratsios.

“As our nation deals with the dynamic challenges resulting from this public health crisis, SIIA’s members and partners are supporting education and our nation’s communities—at all levels—as they transition to or extend their online learning capabilities,” said SIIA President Jeff Joseph. “Tech for Learners will assist educators and school administrators in identifying the EdTech solution that best fits the specific needs of their school, student population, and educational community—from distance and online learning to remote administration and telework. Our hope is this will provide them, along with parents and students, some peace of mind and certainty in these uncertain times.”

ITEEA President Delivers Address to Members

ITEEA’s 2020-2021 President, Dr. Philip A. Reed, DTE, recently shared a video “President’s Address,” which is now available to view at https://youtu.be/d2pJlANJezc.

New York State STEM Education Collaborative, Inc. Cancels Its 2020 STEM Education Summer Institute

Dear NYSSEC Family,

We really don’t know how far out and how impactful the Coronavirus will go, but because of the major long-term disruption we are now experiencing, our planning team has decided to cancel the 2020 Summer Institute. We will be communicating with you as this year progresses.

We are hoping that everyone who receives this notice is able to remain healthy, along with your family, colleagues, and friends.

Many thanks for all that you do with expanding and strengthening STEM-STEAM learning.

Be Well and Be Safe,
Frank Roma, PE - NYSSPE
NYSSEC President
Integrated science, technology, engineering, arts, and mathematics (STEAM) activities provide opportunities for students to creatively engage in authentic problem-solving activities. Each of the subjects focuses on problem solving in different ways. For example, engineering and art are similar in their design processes: identify a problem, brainstorm possible solutions, prototype, test, and improve based on data or feedback (Bequette & Bequette, 2012). An emphasis on problem solving is often codified in standards. For example, the first standard for mathematical practice in the Common Core State Standards and the first science and engineering practice in Next Generation Science Standards focus on defining and solving problems (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010; NGSS Lead states, 2013). Standard 10 in ITEEA’s Standards for Technological Literacy focuses on “understanding the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving” (p. 210).

Equally as important, though, is the emphasis on solving authentic problems. Authentic activities have a combination of ten design characteristics: real-world relevance, ill-defined problem, complex tasks requiring ongoing investigation, multiple perspectives, collaboration, reflection, interdisciplinary connections, integrated assessment, polished products, and multiple interpretations and outcomes (Reeves, Herrington, & Oliver, 2002). As Roberts and Chapman (2017) noted, “The big idea is that the problem is grounded in the real

by

Thomas Roberts and Jerry Schnepp

building problem-solving skills through STEAM

STEAM activities provide a context for authentic problem solving and have the ability to reach more students than science, technology, engineering, and mathematics (STEM) alone.
world but is open for interpretation, complex enough to require sustained work with the help of peers, layered to require reflection, and results in a variety of tangible solutions” (p. 16). STEAM activities provide a context for authentic problem solving and have the ability to reach more students than science, technology, engineering, and mathematics (STEM) alone. Cook, Bush, and Cox (2017) noted, “STEAM teaching is about the student rather than the subject areas—students may see themselves not just as future scientists or engineers but also as designers or creators” (p. 86). This shift broadens applications and contexts in which problems can be explored.

Informal learning opportunities provide an ideal setting in which students can engage in authentic problem solving. STEAM is particularly useful in these settings. Teachers often do not have the opportunity to facilitate in-depth STEAM projects in formal school settings due to time, resources, and pressure to cover material for high-stakes tests (Meyers, et al., 2013). However, informal learning experiences can complement formal learning by giving context for in-class lessons and exercises, providing access and opportunity to authentic environments and professionals, and by extending school learning through application-based hands-on learning (Roberts, et al., 2018). Informal learning environments are typically organized in a way that encourages learning through real-world examples (Meredith, 2010; Popovic and Lederman, 2015), which provides an opportunity for students to engage in authentic problem solving.

With these considerations in mind, the authors designed a week-long STEAM summer camp that focused on authentic problem-solving through art and robotics. The camp was hosted at a local art museum in the Midwestern U.S. and consisted of high school students. It was facilitated by an art educator and two university faculty members, one a computer scientist and the other a STEM educator. In designing the camp, the facilitators sought to encourage the development of students’ introductory proficiency with coding while providing opportunities for students to develop interpersonal skills. The two formal goals of the camp, then, were to provide access and opportunity for learning to code and to develop students’ abilities to communicate, collaborate, and apply critical thinking and creativity to solve problems.

These goals were situated within the context of the designed world. Standards for Technological Literacy describes the designed world as “the product of a design process that provides ways to turn resources—materials, tools and machines, people, information, energy, capital, and time—into products and systems” (p. 140). The facilitators used increasingly complex challenges to engage students in authentic problem solving in the designed world. Table 1 contains a timeline of the camp. The first four days were spent at the art museum where students worked with Arduino kits to learn basic programming that was then incorporated into art projects. In addition to creating projects, students spent time guided through the galleries to glean essential insights from featured pieces that could be synthesized into their

Table 1. Camp Timeline

<table>
<thead>
<tr>
<th>Day</th>
<th>Activity</th>
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<tbody>
<tr>
<td>Monday</td>
<td>• Introduction to camp, Sound Ball collaboration exercise</td>
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<tr>
<td></td>
<td>• Marshmallow challenge</td>
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<tr>
<td></td>
<td>• Individual reflection</td>
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<tr>
<td></td>
<td>• Learning to sketch</td>
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<td></td>
<td>• Introduction to Arduino hardware and first coding exercise</td>
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<td></td>
<td>• Group reflection</td>
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<tr>
<td></td>
<td>• Individual reflection</td>
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<tr>
<td></td>
<td>• Debrief</td>
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<tr>
<td>Tuesday</td>
<td>• Painting with electronic light project</td>
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<td></td>
<td>• Sketching</td>
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<tr>
<td></td>
<td>• Visit museum collections</td>
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<tr>
<td></td>
<td>• Painting in the studio</td>
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<tr>
<td></td>
<td>• Coding tutorial for LED light control</td>
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<tr>
<td></td>
<td>• Individual coding for project</td>
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<td></td>
<td>• Reflection</td>
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<tr>
<td>Wednesday</td>
<td>• Continue painting in the studio</td>
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<tr>
<td></td>
<td>• Presentations and critique</td>
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<tr>
<td></td>
<td>• Coding tutorial for sensor input, push buttons, and servos</td>
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<tr>
<td></td>
<td>• Coding exercise</td>
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<tr>
<td></td>
<td>• Group brainstorm for Steampunk Sculpture project</td>
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<td></td>
<td>• Visit the sculpture garden</td>
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<tr>
<td></td>
<td>• Sketching</td>
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<tr>
<td></td>
<td>• Building and sculpting in groups</td>
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<tr>
<td></td>
<td>• Presentation and critique</td>
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<tr>
<td>Thursday</td>
<td>• Continue building sculpture</td>
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<td></td>
<td>• Troubleshoot electronic aspects of sculptures</td>
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<tr>
<td></td>
<td>• Presentation and critique of sculpture project</td>
</tr>
<tr>
<td></td>
<td>• Reflection</td>
</tr>
<tr>
<td></td>
<td>• Prepare for visit to Bowling Green State University</td>
</tr>
<tr>
<td>Friday</td>
<td>• Visit the Bowling Green State University Campus to tour the Robotics and Mechatronics labs, the Visual Communication Technology labs, and the Collab Lab.</td>
</tr>
</tbody>
</table>

b
work. On the final day, students traveled to the university campus to see applications of art and robotics, visit research labs, and to present their projects to members of the university community.

In the following sections, we highlight project details, student reflections, facilitator reflections, and lessons learned.

**Marshmallow Challenge**

This classic design challenge was used to introduce students to problem solving and group norms for the camp. Students worked in pairs to build the tallest tower they could using dry spaghetti and marshmallows. After the first round, students collectively reflected on what worked well and what did not. They were then given three minutes to brainstorm for round two. At the end of round two, students engaged in a similar reflection exercise.

Throughout the students’ reflections, one lesson consistently emerged: the importance of failing fast. The students who were most successful in building tall towers did not get distressed or delayed by minor setbacks. As Devon described, “mistakes are mistakes until you learn from them and make them not mistakes.” Instead, they failed fast by quickly analyzing the problem and working on a solution. The quick, iterative process of trial and error did not waste time focused on problems; instead, it emphasized the importance of implementing solutions, evaluating them, and optimizing based on what was learned.

This activity also emphasized the importance of collaboration. Students worked with partners to plan, build, and reflect. While Jaquan said he “learned to work together” in his design journal, Kiara offered a deeper insight. “I learned that you work better when you are in a group that has multiple ideas to try rather than working by yourself,” she wrote. As Kiara noted, collaboration was not just a way to share the workload of building a tower. She focused on the importance of multiple ideas. The variety of perspectives students bring to group work is valuable as they search for solutions to challenges they are given.

Facilitators noted that the more disparate the approaches, the more creative the solutions. This observation reinforces the benefits of failing fast. When students fail fast, they can explore multiple varying approaches iteratively. That is, they try an idea, test it, and improve it, ultimately leading to an optimized or innovative solution. Sometimes failing fast during the testing phase motivates students to arrive at creative and unconventional solutions.

**Visual Communication Through Sketching**

The next project students worked through was a sketching exercise in which they were introduced to the basics of sketching using a dot, a line, and an arc. Eventually, students were asked to draw a picture when they were given a seemingly random word. For the more technically inclined students, this activity initially posed many problems, as several did not describe themselves as creative or artistic. Joshua expressed this as he noted the sketching activity required him “to be more creative than” usual. As Joshua’s reflection suggests, this exercise was not only meant to boost students’ sketching confidence, but also to encourage them to think creatively about how to represent different images. As students progress through grade school into high school, they typically spend more time writing than drawing. Hence, these students felt slightly uncomfortable communicating in this modality. Tracy reflected, “I learned to think differently about sketching.”

Joshua did not just see sketching as a creative exercise; he also saw it as a tool for brainstorming. “I would like to know a bit more about sketching because it will allow me to be quicker at getting an idea of what I want to do,” he wrote in his design journal. Joshua’s perspective also connects to a previous lesson learned: failing fast. As a tool, sketching would allow Joshua to engage in divergent thinking, work through multiple ideas, learn
from mistakes, and make changes as needed. Thus, sketching was not just an important means of being expressive, it was also an important tool for creating.

**Painting With Light**

The next project required students to integrate computer coding, electronic components, and acrylic paint on paper. They conceptualized a painting that would feature programmed LED lights as part of the composition. The art educator discussed how artists use light in paintings and took the students on a quick tour of the museum to highlight specific techniques artists use. The computer scientist introduced students to coding with the Arduino kit and focused on basic understandings of programming. Specifically, students learned how to program LED lights to turn on and off, fade, and blink using variables, inputs, outputs, and essential control structures. With the basics of both subjects covered, students were told to create some sketches that could later be turned into a painting that incorporated the lights. Figure 1 shows the variety of sketches students created for their painting. As Figure 2 shows, the students depicted very different items in their paintings, ranging from a football field to a dinosaur to one student's conceptualization of the universe.

Students overwhelmingly identified the unique skills they learned by completing this project. Tyler offered that he learned “how to somewhat paint and how to fade LEDs successfully. Also, how to use the loop” when coding. Eva commented, “I learned more about painting and mixing colors.” Devon focused on the technical aspect of wiring the Arduino breadboards. He noted, “wiring [sic] is kinda fun but somewhat difficult” (Figure 3, page 8). Devon’s response focused on a skill he developed but also on the process, noting that there is an element of fun in a challenge.

Other students also reflected on the process of creating. For example, Kiara “learned things don't always go as planned... [specifically] where the lights didn't do what I wanted.” Similarly, Jaquan reflected, “how hard it is to do combining.” When students encountered unforeseen technical problems, it did not deter their progress. In fact, they found ways to pivot their idea and take a new direction, leading to a more creative and innovative project. The experience helped teach these students to embrace setbacks and look for serendipity as a path to creative solutions. Even when things did not go as planned or students faced an obstacle, it was a productive challenge that students viewed as fun. Tyler surmised, “it is really fun, and I can see how I could create more things to entertain people.”

**Steampunk Kinetic Art**

This project required students to design a sculpture with a steampunk aesthetic that incorporated robotics by having some part of the sculpture move. The art educator led the group on a walk through the museum’s sculpture garden to talk about form and kinesthetic components of the sculptures. The computer scientist built on students’ Arduino understandings to teach students how to program different motors, incorporating several external libraries to expand functionality. Students were then put into groups of 2 or 3 and created sketches of potential sculptures. After their brainstorming, they picked one sculpture and decided on the materials they could use. As Figure 4 (page 12) shows, the students created a variety of sculptures, ranging from a steampunk head to an anachronistic clock.

Students’ reflections focused mostly on the skills they learned in coding and art making. However, Joshua indicated that the lessons learned in previous projects influenced his perceived value of iteration in the problem-solving process. For example, in explaining what he enjoyed about the project, he noted, “it's fun and entertaining to fail and fix my mistakes over time.” The facilitators had highlighted the importance of this lesson earlier in the week; however, Joshua did not embrace it until he had experienced it throughout the projects he completed. By the time he reached this project, he had incorporated it into and claimed it as part of his problem-solving process.
Facilitators also observed a choice overload (Scheibehenne, Greifeneder, & Todd, 2010) brought on by the open-ended nature of the project. Students were able to choose from a variety of materials including wood, metal, foam, paint, hot glue, and/or wire, while also creating any subject they wanted. Instead of observing creativity, the facilitators noticed a selection paralysis in which students took much longer to decide on a direction for their projects. Thus, one important lesson is that while open-ended projects are required for authentic problem solving, constraints help trigger creativity, as unlimited choice can have unintended consequences (Brockett, 2006).

Conclusion

When designing this informal STEAM summer camp, the goals of the camp were to provide access and opportunity for learning to code and to develop students’ abilities to communicate, collaborate, and apply critical thinking and creativity to solve problems. As evident in the students’ reflections, these goals were achieved through the lessons they learned. Students learned the importance of multiple ideas in collaborating, how to learn quickly from mistakes, and how to troubleshoot when they encountered problems in completing their challenges. They also identified discipline-specific skills, such as Tyler commenting that he learned how to use a loop, or Devon discussing the difficulties of precisely wiring an Arduino breadboard. More broadly, students learned how to paint, sculpt, or “how to code,” as Jaquan said. Still, reflections clearly indicate that while students benefited from the exposure to code and were able to creatively incorporate it into their art projects, they had not acquired the level of mastery associated with sustained learning.

Even though all the students were high school aged and “digital natives,” their familiarity with technology did not translate into proficiency in coding. It is common to mistake digital natives as being technologically proficient due to the omnipresence of technology in their daily lives. As the facilitators experienced in this camp, however, there is “mounting evidence that [suggests] many young people’s actual use of digital technologies remain rather more limited in scope than the digital native rhetoric would suggest” (Selwyn, 2009, p. 372). Indeed, working with a computer scientist allowed students to learn the basics of coding (e.g., variables, inputs, outputs, and basic control structures). Students’ reflections regularly identified the coding skills as things they learned. Thus, while many lessons were gleaned from this camp, one of the most salient is the importance of understanding how to scaffold digital natives’ learning experiences with technology so that they not only can interact with technology but use it as a form of creative expression.

While students identified coding as one thing they learned, they only received an introduction. The greatest learning the facilitators observed was in students’ emotional intelligence. This was demonstrated through their increasingly successful collaborations throughout the week. The collaborations included more supportive behaviors from students, such as when students would pause their work to help other students when they struggled. This eagerness to help and to share their burgeoning knowledge with one another demonstrated the cohesion of the group. Ultimately, due in part to the norms set on the first day and reinforced throughout the camp, students valued each other’s progress as much as they valued their own. This empathetic behavior was unexpected, yet very important in the camp’s success.

The positive experience of this week-long camp was evident in students’ reflections and in their abilities to successfully apply the new skills they learned to complete the challenges they were given. Because these challenges were presented as authentic,
real-world problems, students were able to work collaboratively for an extended period of time to create “a variety of tangible solutions” (Roberts and Chapman, 2016, p. 9). The openness of each task provided students with the opportunities to engage their diverse interests, backgrounds, and experiences to create tangible products to meet the demands of the challenges. Moreover, the coding process was demystified as students consistently expressed more interest and more ability to engage in coding after the camp. Using code for creative projects empowered students to persevere in learning to code and led to increased interest in further learning about coding.

References

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This is a refereed article.

BRAINSTORMING STEM PROJECTS FOR NEXT SCHOOL YEAR?

Sign up for ITEEA’s REACH Challenge - an innovative design-thinking project for middle, high school, and college STEM programs. Teachers and their students use their STEM skills to REACH a member of their community who has a challenge to overcome, and design a viable adaptive or assistive technological solution to their problem. When teachers sign up, they get an Educators Toolkit with everything they need for the project, including slides, worksheets, case study topics, videos, and activities. Completed projects can be submitted to ITEEA for an opportunity to earn awards and funding for their STEM program!

LEARN MORE TODAY AT www.Reachchallenge.org
Shot in the Dark

In the summer of 2016, an application was submitted for a Fulbright grant to teach in China. A sabbatical was scheduled for the fall of 2017, and this was one of many opportunities that an American professor chose to explore for that time. Though the educator has had a successful career in education, he possessed reservations regarding the likelihood of being selected for such an opportunity. With the encouragement and support of colleagues, the required paperwork was completed and submitted a year prior to the planned sabbatical. The educator continued to seek alternative plans until contacted in early 2017 by the Fulbright organization...he was going to China.

The educator proposed to aid in the preparation of new and practicing teachers interested in providing contemporary Technology and Engineering Education to

Fulbright experience: ITEEA Chinese center

A visiting teacher must be aware of their teaching practices and recognize that they may differ (significantly) from those of the institution/area where they are placed.

by

Mark Mahoney
Fulbright experience: ITEEA Chinese center

students. For the sake of this opportunity, the application was positioned to work directly with a college/university in the designated area of China to which the teacher was assigned—mainland or boundary. The intent was to work collaboratively with the faculty/staff at the assigned college/university to structure practical, hands-on learning opportunities and environments founded in the diverse subjects associated with Technology Education – General Technology Subject. Topics that were proposed included the following:
- History and development of Technology Education
- Specific content knowledge relating to each of the designated modules
- Subject integration including Science, Engineering, Mathematics, and Art
- Learning Activities, Projects, and Assessments
- Classroom/Laboratory setup and maintenance

These opportunities were designated for either candidate teachers and/or practicing teachers from other disciplines. The form and content of these opportunities were to vary dependent on the college/university assigned as well as the needs of the surrounding community. For example, if placed in a more rural area, the focus of the Technology and Engineering Education may lean toward agricultural technology rather than robotics design/construction. With this understanding, the responsibilities would have included both traditional classroom/laboratory experiences as well as professional development seminars. Site visitations to review existing programs and/or highlight programs of excellence as potential models were also proposed.

Why China

China has been a topic of much consideration with regard to curriculum and student education. Many educator colleagues have prepared students to progress into positions of industry/manufacturing, education, and/or varied trades. It is believed that for someone to be capable and competitive in an ever-changing world of advancing technology, that they must have a concept of the global economy and its participants. Therefore, China has become a regular topic of discussion and debate in classrooms. Over the past thirty years, China has exhibited tremendous development of society and economics through large investments in manufacturing and infrastructure. The Chinese educational system has seen a corresponding growth in development.

An example of this progression is founded in the current, contemporary form of Technology and Engineering Education. Its roots can be traced back to the Soviet model of polytechnic education from the 1950s—alleged to serve political needs rather than educational or societal (Jiang, 1996). By the 1980s, the Labour-technical education model emerged as a much broader interpretation—addressing both political and economic necessities (Feng, Siu, and Gu, 2011). However, this evolution was not compulsory, nor did it provide education beyond industrial training. By the 1990s, early forms of Technology Education began to emerge to the point where it was recognized as an independent subject. As of today, Technology Education in China is comprised of two main categories—Information and General Technology. Both require compulsory foundational courses with a variety of electives that may be offered (by school availability or community need) (Feng, Siu, Gu, 2011).

The Ministry of Education in China has been working to prepare a new generation of teachers through traditional, in-service, and online training (Ministry of Education, 2003). However, even these efforts have left several programs without adequately prepared teachers and/or facilities. There are several suggestions as to why this condition persists, including lack of available resources, assessment requirements, funding, and/or training programs at the collegiate level (De Vries, 2002). At the time of the Fulbright application, the International Technology and Engineering Educators Association (ITEEA) was in discussion with agencies in China to establish a resource center. This center was proposed to provide additional support and resources to continue the efforts set forth by China's Ministry of Education. The teacher wished to participate in this journey by adding another ally to the purpose. There was already a collection of quality institutions engaged in this work (such as Nanjing Normal University), and the teacher was hopeful that they could be supportive in their continued development.

Preparing to Teach in China

The American educator has been fortunate to teach a variety of subjects at various levels during a teaching career that includes middle school, high school, and college/university levels. Over seventeen years of classroom teaching, personal teaching methods have evolved. Like most inexperienced teachers, early lessons relied heavily on behavioral teaching methods. The simple transfer of information was comfortable and familiar.
Though the behavioral method is quite efficient for the transfer of information and basic skills, it only addresses the most primary of a learner’s cognitive process—lower levels of Bloom’s Taxonomy. It took guidance and support to transition from the behavioral process to more of a constructivist teaching method. The constructivist method transitions the teacher from an authoritarian figure (lecturer) to that of a guide (facilitator) (Harden & Crosby, 2000). It relies on a community of learners, working collaboratively to solve problems and arrive at conclusions with the guidance/support of the teacher. This method is complementary to the behavioral method and works well for moving students to higher levels of cognition. It is also very applicable to hands-on, project-based learning where skill development in critical thinking and problem solving is sought. These facets have been embraced by the teacher in his current practice for the benefit of student learning.

These, of course, are not the only approaches to developing student learning. In fact, China’s own history demonstrates cultural, political, and economical stimuli that have influenced the structure of the current educational learning theory. A foundational element of China’s educational culture is based on the teachings of Confucius. This early form of educational structure focused on both society and individual aims—with former taking precedence (Chen, 1990). Others’ needs supersede the individual’s, and loyalty toward society and family were paramount. Such a model has yielded an educational system based on hierarchical structure with a strong emphasis on etiquette, honesty, and meticulousness (Corcoran, 2014). Therefore, communication within this system requires understanding and respecting this history and its implications. A foreigner must establish a Guanxi (personalized network of influence) to effectively communicate and network within the existing hierarchy (Corcoran, 2014). To build such a network, an individual must be open, honest, and as respectful as possible while also reciprocating any kindness that is offered by hosts and/or colleagues (Elashmawi, 2001).

Though Confucius’s teachings have endured even into modern Chinese society, the educational model has evolved through outside influences. Such influences include German, Soviet, and Western practices (Wu, 1991; Zhou, 2005; Wang, 2005). Each has brought its own interpretation and value of liberal and vocational education into China’s educational system. Today, the system is an amalgam of these influences as is evident in the teaching methodologies commonly practiced—behaviorism, liberalism, and constructivism (as examples) (Wang, 2009; Corcoran, 2014). Due to this reality, it is vital for any teacher/educator (foreign or domestic) to be prepared to address and demonstrate a variety of teaching methodologies. This will be for the benefit of any candidate and/or practicing teachers for at least two simple reasons:

1. Teachers should not be limited to a single teaching methodology:
   - They need to feel empowered-supported to find the method that works best for their teaching style, subject, and student learning.

2. China needs to establish its own educational identity that celebrates its history while addressing the country’s objectives:
   - Continuing to borrow from other nations will only perpetuate the turmoil.

This was important to understand because a visiting teacher must be aware of their teaching practices and recognize that they may differ (significantly) from those of the institution/area where they are placed. Removing oneself from the role of teacher (a position of authority) to that of a facilitator may not have been readily accepted (depending on the practice/influence at the assigned institution). Therefore, an individual must be ready to respect the practices of the institution and its surrounding community and establish/foster a Guanxi prior to demonstrating possibly challenging methodologies.
Teaching in China

The American educator was granted a Core Fulbright Teaching Scholarship to help prepare graduate teaching students (masters and Ph.D.) in STEM Education. Arriving in late August, a group of American educators spent a handful of days in Beijing being trained at the U.S. Embassy by State officials. After completing the training, the collection of scholars was sent off to their respective institutions for the duration of their stay. The educators were provided a wèi bàn (professional representative of the university) and two graduate students functioning as teaching assistants to ease the transition and to aid in systematic responsibilities.

The educator was fortunate to be placed at Nanjing Normal University, the eventual location of ITEEA’s China STEM Center. Additionally, Dr. Jianjun Gu, Dean of the School of Education Science, would be the acting supervisor. He is directly responsible for the development and assessment of STEM education for China’s Ministry of Education. Dr. Gu continuously worked with students, colleagues, and contacts on collecting data from across the country. His students (all graduate level) worked diligently, processing the national data for the Ministry of Education. Dr. Gu invited the teacher to present together at a national conference in Nanjing on STEM Education. They discussed STEM Education in China and the U.S. and discussed possible future ventures between institutions and associations like ITEEA. This assignment also provided the teacher additional opportunities to present at conferences, local schools, and colleges/universities of engineering, education, and technology. The teacher presented on STEM Education in the U.S. and China, Project-based learning, Transportation Safety, and Energy supply and demands.

The American educator was asked to teach two graduate classes during a brief stay: (1) Teaching Methods in STEM Education and (2) STEM Laboratory Project Design. This was the first time the teacher had the opportunity to teach graduate level courses. After some curricular adjustments due to limited equipment and material access, the courses began. Each class was scheduled to meet once a week. The days, times, and locations of those regularly shifted due to scheduling/programming that was unfamiliar. It appears that changes of this sort were common. However, the other faculty and staff were extremely helpful and patient.

The students were found to be extremely polite, professional, and respectful. When arriving for class, the students sat toward the front of the room, eagerly awaiting instruction. Their retention of information was impressive—particularly in mathematics. After a few classes, the teacher began to modify the learning environment. The reasoning for the change was explained and, for some, the discomfort was clearly observed. As an example, one day the teacher arranged the chairs into a circle—including their own. The students arrived and were directed to sit in the circle. Students were visibly confused by the new arrangement. It was explained that this was part of the lesson—an example of different classroom environments and teaching methods. After some apprehension, the students acquiesced, and the group began to discuss what the students were feeling. It soon became apparent that the circle was not the primary concern; rather it was the fact that the teacher was sitting as part of the circle and not at a position of authority. This was a notable turning point for the classes. Following this session, the teacher relocated their desk and workspace into the student lab space on the lower level of the building. This was done to be closer to the students while also continuing to build trust and communication between the teacher and the students. Additionally, the lab (at that time) was not in good working order. Much of the equipment needed repair, and many of the students had never used it.

The relocation greatly enhanced the relationship between the students and the teacher; a Guanxi was beginning to be formed. The teacher and students would sit together and discuss projects, English writing, graduate schools, and opportunities in the U.S. Students began to more freely ask questions about education and education systems. They began to discuss various ways of approaching projects and teaching. Students developed and presented lessons that incorporated different teaching methods. At the close of the courses, all the students’ submissions were collected and combined into a single digital folder for them to share. Lessons ranged from primary to secondary grade levels and encompassed all variations of STEM Education. Additionally, all teaching styles and methods were equally represented. It was the teacher’s intent to expose students to alternative ways of instruction/learning, not to forcibly alter their preferred methods or approaches.

Going Forward

The educator intends to continue to work with Dr. Gu on the development and assessment of STEM education throughout China. The development of more project-based learning with measurable outcomes for implementation in China’s educational system was discussed. The teacher also anticipates being involved with the continued development of the ITEEA STEM Center at Nanjing Normal University. At the end of the experience it became apparent that a new site for the ITEEA-supported laboratory space had been identified, and plans were underway for setting up what would become the national hub for STEM education in China. The teacher was also privileged to present at Dalian University of Technology. There, future research projects were discussed with Shengchuan Zhao, Professor and Dean at the School of Transportation and Logistics. He was interested in perspectives related to transportation in the U.S. and China as well as the communication of such through various teaching methods. They discussed developing texts/lessons that would
be focused on the clear communication of transportation system design and considerations to entry-level engineering students.

For the American educator, it was a great honor to represent the country as a Fulbright scholar and act as a representative for ITEEA; honors that would have never materialized if not for the support of fellow educators, colleagues, and friends. The Guanxi that was established has forever impacted the teacher—in both teaching and scholarship. The students, especially, have become part of the teacher’s family. For anyone interested, there are great opportunities in STEM Education throughout China. The fact that ITEEA has an existing and direct connection brings those opportunities ever nearer. Additionally, the Fulbright organization is a wonderful program prepared to help students, teachers, and professionals experience the world for the betterment of education and humankind. For those interested, it is important to know that the Fulbright organization, though competitive, is keenly interested in attracting new and innovative professionals (at all levels) into the association. If you are interested in finding out more about opportunities in China and/or the Fulbright process, please feel free to contact the author of this article at the email address below.

References


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This is a refereed article.

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Introduction

In recent years, the impact humans have had on the world, and specifically the world's oceans and marine life, have surfaced as one of the most continuously discussed topics in news feeds and other media outlets (Elliott, 2018). Specifically, current research and well-known stories have detailed the disastrous effects—direct and indirect—humans have had on the oceans (Ocean Priorities, 2009; Weiss & McFarling, 2006; Yong, 2019). The impact of human activity on marine life through unsustainable actions, recreational activities, pollution, and consumption patterns continues to lead to calls for attention and action of individuals worldwide. Many organizations, researchers, and individuals have sought to raise awareness of the importance of ocean conservation and sustainable actions in the hopes of counteracting the impacts of human-environment interactions by shaping how humans view, use, and manage the ocean environments (United Nations, 2019; United Nations Department of Economic & Social Affairs, 2014).

Today, the world's oceans show the results of many subtle and profound changes (Davidson, et al., 2012); for example, recent research shows that no area of the ocean remains completely unaffected by human influences (Halpern, et al., 2008). Further, investigation shows that approximately forty percent of our vast oceans are strongly affected by multiple human impacts (Halpern, et al., 2008). These include—but are

SMART buoys:
integrating data visualization and design
to reduce ocean-life casualties

by Vanessa Santana, Scott Bartholomew, William Rowe, Vetria Byrd, Greg Strimel, and Kevin Han
socially relevant contexts
certainly not limited to—pollutants (i.e., chemical contaminants, debris, and even sonar noise), by-catch, shipping, overharvesting, global warming, ocean acidification, and the altering of food webs (Halpern, et al., 2008; Schipper, et al., 2008). Negative impacts to natural environments and wildlife, such as these, continue to increase globally as the demand for space and resources continues to grow in order to accommodate the world’s population.

Oceans overall continue to be affected by changes in temperatures, acidity levels, and even available nutrients; these impacts transition to the living things found within these waters. Specifically, marine mammals—key players in our ecosystems—have found themselves in the crosshairs of many of these changes (Schipper, et al., 2008). The International Union for the Conservation of Nature (IUCN) currently identifies one-fourth of marine mammals to be at risk of extinction (Davidson, et al., 2012), and estimates show that approximately three-fourths of marine mammals experience high levels of human impact within their geographic ranges; impacts from activities such as fishing, shipping, pollution, sea surface temperature change, ocean acidification, invasive species, oil rigs, and human population density (Schipper, et al., 2008).

Among marine mammal mortality rates, the single greatest threat has been found to be accidental mortality (i.e., vessel strikes and fisheries’ by-catch [unwanted catch collected during the fishing of other species]) (Schipper, et al., 2008). In Florida, one case of impact became the subject of multiple news stories, as it was found that one-fourth of all recorded manatee deaths had resulted from manatees being struck by boat props (Calleson & Frohlich, 2007). Manatees, however, are not the only documented cases of high accidental mortality rates within marine mammal populations. Every year thousands of seals are also killed by boat props—casualties resulting from boats inadvertently speeding over feeding seals, with often fatal results. Although these casualties are not as drastic in numbers within all marine species, the issue of ecosystems being affected by human activity (such as boating) is universal and has had an adverse effect on the environment and marine life populations (National Ocean Service, 2019).

Innovations for Saving Marine Wildlife

Over time, a range of approaches and methods have been used in an attempt to study the behavior and movement of marine animals. Only recently however, has data been provided and available publicly for a variety of species. Sharks, for example, are studied using pop-up archival tags (PAT)—a type of tag that collects various information about specific species patterns, such as the depth of dives (calculated from pressure), ambient light used to estimate and track locations, as well as internal and external body temperature (Musyl, et al., 2011). New techniques and devices such as these are advancing our un-
nderstanding of animal species and their environmental patterns, which may provide individuals with valuable information needed to continuously create and innovate methods of aiding marine wildlife.

As GPS technology has resulted in mapping and tracking data for a variety of marine life, it is possible that accidental mortality incidents among marine animals can be reduced as boaters are made more aware of their surroundings. For example, it is feasible that GPS technologies could be used to alert boaters to slow down around, or avoid, high-population-density areas of marine mammals. To build upon this concept, the authors developed a lesson to provide students with the opportunity to engage in core design practices that are informed through data visualization techniques of marine wildlife patterns to reduce the amount of marine-life casualties. In this lesson, students are tasked with creating a solution—through the use of engineering design—to address one of the greatest threats to marine animal species by reducing boating accidents. Specifically, students are tasked with designing a buoy that will provide boat drivers with a warning about nearby marine life so they can respond appropriately.

**Engineering Classroom Connections**

In this lesson, students engage in analyzing generated data from OceanTracks.org (Figure 1), identifying patterns and creating a data visualization model based on their own research of scientific data in order to inform design decisions. Students consider the interactions from their chosen combination of variables involving marine wildlife movement/patterns, human impacts, and environmental factors in order to develop a visual representation of a geographic location with high marine wildlife activity overlapping regions of high human impacts. Students are challenged to use their newfound insights derived from their visual model to drive design decisions as they design and prototype an automated buoy for a specified “ocean” region in the hopes of alerting boaters of nearby marine life.

This lesson incorporates current and relevant global issues in the hope of providing a way to engage students in a multitude of engineering and technical concepts, while also developing crucial applied skills necessary for the 21st century, such as critical thinking, information literacy, and technology literacy (Dean, et al., 2010). Additionally, the many parallels between the engineering and visualization processes may reinforce critical areas such as collaboration, creativity, imagination, critical thinking, and problem solving (Byrd, 2018). As students work through the engineering process and visualize the data associated with the project, this lesson facilitates informed decision making with visual representation of the data (created by the student) to support those decisions and further reinforce engineering and data visualization principles.

The lesson includes a classroom design challenge (Figure 2, page 21) and the associated lesson designed to integrate STEM content through the authentic and socially-relevant context of a current global issue, marine-life causalities. It is clear that news stories and policies are reflecting the need for individuals to be informed of the impacts humans have on the earth, not only on a large scale, but also through small, everyday choices. Integrating the authentic and socially relevant context of a global issue within lessons not only aids to engage students, but also promotes the importance of working towards imagining, designing, modeling, and even testing potentially viable solutions to the problems they see—and hear of—around them.

**Conclusion**

It is the authors’ hope that providing an engineering challenge that requires the use of data to inform design decisions will call attention to the value and advantages that data collection and analysis can provide to students during their decision process. While the processes of tinkering and trial and error within an engineering/technology classroom are common, it is also important for educators to provide students with opportunities in which research and data visualization can be used to inform and drive design decisions. It is crucial that students are knowledgeable of—and develop experience with—a multitude of processes and principles that they can employ to approach the challenges and problems they hope to solve. Therefore, providing socially
relevant design opportunities for students, while also incorporating challenges requiring research and data, can hopefully result in a more effective solution than what could be achieved through simple trial and error.

NOTE: The lesson plan for this activity is online at: www.iteea.org/TETMJ20SRC.aspx

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This is a refereed article.
What has been your secret to success as an educator and educational leader?
I believe educators have a thoughtful role in providing opportunities for learners by challenging them with unusual learning opportunities, new technologies to advance their learning, and ill-defined activities making them think collaboratively and grow in their confidence and in making career decisions. I was always a nontraditional learner and refused to be put into the normal “female” roles—I joined the Air Force at age 20 and learned about electronics, avionics, and weapons release bomb computers utilizing gyroscopes. This was back when women were more the exception than the norm in the military and especially in such a highly technical field. This experience was the pivotal point in my life as it taught me to work hard, keep learning, and instilled in me the leadership models to emulate.

As a leader, I use the same process I use with learners, as I like to challenge my co-workers to stretch their skills and styles to undertake ill-defined projects and to venture into new opportunities. I support the growth of those whom I lead; I allow them to work on projects without my assistance and only intercede when asked. Leading others in today’s educational arena—which for me is higher education—can be tough, as we’re faced daily with new initiatives and new concerns for and about our students. Leadership should be focused on helping guide those who work with you to build their skills toolbox to further their leadership goals.

What lessons from your parents have you carried through the years?
Perseverance is the most important thing I learned from parents. My father worked until he was 90, and my mom went back to college at age 50 and graduated with a master’s degree. They always challenged me to look at every situation from multiple perspectives, analyze the different choices, and then make a decision. If the decision was wrong, admit your error, correct the choices, and realign your trajectory from that point on.

What have you learned that you would want to pass on to younger generations?
Face every opportunity and roadblock as a learning opportunity. Consider what you learned, what you can change or adapt, and take away a positive from every job, educational course, or training you undertake.
What special challenges have you faced as a woman in a mostly male-dominated field?

Early in my career in education, although I was included at the “table” discussions, I believe I had no voice in the decision-making process. This was especially true in terms of not being recognized for my perspective or prior knowledge regarding decisions that affected the programs and leadership of the institution. This has changed somewhat in the past five years, but I believe all institutions need more diverse input from all stakeholders, especially regarding the multifaceted and ever-changing area of STEM education.

Do you have any recommendations for creating a more inclusive community/classroom or words of advice for working with underrepresented populations?

We need to recruit more underrepresented minorities (URM), and this includes women into STEM Career fields. I believe we need to stop promoting earlier concepts that say we need to focus solely on females, but rather focus directly on all of those who stay away from STEM for whatever reason. This must start early in education, at the primary level, so that all learners get a firm grounding in mathematics, science, and the engineering process. We need to stop the “I’m not good at math,” as we use math daily just to get up and live our lives, which requires some math proficiency. Build on that and don’t take the flip answer stated above, but instead challenge all to develop those mindsets and skills needed for STEM success. It is not a male career field; it is a career field where all can earn a good living wage. As STEM educators, we owe it to all our learners to have equal opportunity to express their joy and love of science, technology, math, and engineering. We must help them develop that joy in STEM by developing their emotional intelligence (EQ). EQ equips students with conceptual understanding of STEM and its place in society. Understanding that self-regulation, motivation, and curiosity for learning are brain-based proven tools to guide the “doing and making” of learners, equips them to be future problem solvers. Research shows the EQ is a more reliable predictor of STEM success than IQ alone. EQ is a distinct combination of emotional, personal, and interpersonal skills that influence our learners’ capacity to cope effectively with real-life integrative STEM problems. Developing EQ also appeals to underrepresented populations in STEM by promoting the social benefit aspects of STEM learning and future STEM careers.

What are you looking forward to next?

Focusing my efforts on reinvigorating our association through the Taskforce on Membership Diversity. Nontraditional thinking is required to appeal to those young career specialists in our field who are changing the face of who and what is integrative STEM education. As an organization, ITEEA wants to capture that vibe and promote how our organization can meld into the “go to” place for networking, ideas, and collaboration on STEM for the future.
"powered and pumped up" with NASA

The NASA engineering tasks proved to be an engaging experience that helped middle school students develop an understanding of the engineering process and a relevant application.

Next Generation Science Standards (NGSS) and the Common Core State Standards for Mathematics increasingly promote the integration of the engineering design and modeling processes into the K-12 curriculum and advocate for problem solving within real-world contexts. The NASA Engineering Design Challenge (EDC), Powered and Pumped Up (www.nasa.gov/glenn-edcs-powered-and-pumped-up), supports these goals. Each EDC presents students with a real-life problem that is introduced by a NASA scientist and is to be solved by teams of students.

Engineering Design and Mathematical Modeling

According to the National Academies of Engineering and the National Research Council’s joint report, the inclusion of engineering in the K-12 classroom is expected to “provide an opportunity to engage with science content in an applied context and introduce students to the field of engineering previously underrepresented in K-12 education” (2012, p. 49-50). Likewise, the emphasis on mathematical modeling is found throughout the Common Core math standards (Council of Chief State School Officers, 2010); for example, “Modeling is the process of choosing and using appropriate mathematics and statistics to analyze empirical situations, to understand them better, and to improve decisions” (p.72).

Mathematical modeling attempts to describe various real-world interactions by explaining their dynamics through mathematics (Quarteroni, 2009). NASA’s Engineering Design Challenges unite both mathematical modeling and engineering design as will be described in the following section.

by Joanne Caniglia and Michelle Meadows
NASA’s Engineering Design Challenges

The objective of NASA’s Engineering Design Challenges (EDCs) is to connect students, at both in-school and out-of-school settings, with the unique challenges faced by NASA scientists and engineers as they design the next generation of aeronautic and space vehicles, habitats, and technology (NASA, 2019). Each challenge includes the following elements:

- A main problem that the scientists and researchers at NASA’s Glenn Research Center are currently studying.
- Supporting science investigations that go deeper into the content and align directly with NGSS.
- Live virtual connections to NASA Subject Matter Experts (SMEs) where participants can discuss their challenge solutions and the SMEs’ work at NASA.
- Opportunities for student teams to submit their solutions to the challenge problem to the NASA Glenn Office of Education in the form of a slide or video presentation.
- Virtual and in-person professional development for facilitators to learn how to conduct the challenges in their own settings (NASA, 2019).

The absence of step-by-step instructions for building prototypes makes the NASA design challenges helpful to educators who want to implement inquiry design in their classroom. The emphasis is for students to understand that engineers must “imagine and plan” before they begin to build and experiment, which is why NASA requires students to draft their ideas before beginning their constructions.

Each NASA Design Challenge features objectives, a list of materials, educator information, procedures, and student worksheets. When appropriate, the guide provides images, charts, and graphics for all of the activities. All activities are intended for students to work in teams of 3 to 4. The activities can supplement curricula during the school day or serve as activities in after-school clubs. The activity guides were also designed to keep material costs reasonable, using items often already found in the classroom. Furthermore, all activities correlate to national science, mathematics, technology, and engineering standards. A list of national standards is included in Appendix A. In addition to the above-mentioned materials, Appendix B provides resources describing the specific challenge identified in this article and context from NASA’s own mission while inviting students to a realistic task. NOTE: Appendices are online at: www.iteea.org/TETMJ20NASA.aspx.

The Powered and Pumped Up NASA Challenge

The authors attended a facilitation training directed by the Glenn NASA program officers and utilized the Powered and Pumped Up Challenge with the students. Using the engineering design process, students designed, built, and improved a stand-alone solar-powered pumping system to move water as quickly as possible between two containers. Students used light-concentrating materials, varying shapes, and structures to maximize the collection of simulated solar energy. The energy was then directed toward a solar cell to power the system and move the water (NASA, 2019).

Before this challenge, three supporting science investigations were conducted to aid students with various elements of the engineering challenge. Each of the following supporting investigations took approximately 10 to 20 minutes.

1. “How Intense Are You?” – Students examined the relationship between light intensity and the distance from a light source.
"powered and pumped up" with NASA

2. “What's the Point?” – Students explored the effect of lenses in manipulating light.
3. “Shed Some Light” - Students used mirrors to reflect light and learned about focusing energy to a desired location.

The sections that follow describe how students applied the engineering design process and their reactions when solving rigorous inquiry tasks.

How Students Met the Challenge Using the Engineering Design Process

Although numerous engineering design models exist, for the purposes of this activity the authors used an EDP that was provided to students and adapted from the Massachusetts Department of Education Center for Instructional Support (Figure 1, page 27).

The process includes identifying a need or problem, planning a design, creating a prototype, evaluating, research, and finally improving the original design. Providing feedback is central to all elements of the design process and demonstrating that the process is not linear.

Identify a Need or Problem

According to NASA's facilitation guide for Powered and Pumped Up, “engineering design begins by identifying a need or problem to be solved, improved, and/or fixed. This typically includes articulation of criteria and constraints that will define a successful solution” (p. 68). Students watched a video provided by NASA’s engineers as they described the problem and identified the need for scientists to one day transport water on Mars (www.nasa.gov/glenn-edcs-powered-and-pumped-up). The authors of this study added the viewing of a clip from the movie, Martian to add relevance and interest. The classroom teacher also utilized videos and articles produced by NASA, which can be found in Appendix B (www.iteea.org/TETMJ20NASA.aspx). The purpose of these supplemental resources was to represent the need for solar power when a water source may not be in plentiful supply.

Following the presentations of videos, reading materials, and explanations by teachers, students had a strong understanding of the problem and extended the problem to Mars. Students felt that the NASA video with educational consultants and directors of research explained the problem, making it seem more real. One student expressed “this is not just another experiment." By the end of the three preliminary investigations, along with video resources, students were able to articulate the problem and identify the goals of the task.

Planning a Design

For the NASA EDC program, “Design” is a central focus and requires two subparts. First students created a set of potential solutions and then compared and contrasted their individual designs with others within their groups. Figure 2 illustrates designs created by students before they were granted permission to purchase materials from a fictional price list (Table 1).

To support the importance of searching for the best solution rather than enacting the first idea that comes to mind, students were asked to draw designs individually and then be prepared to suggest a rationale for their choice of design. Following this period of individual effort, the four drawings became one, and the group found the “best” solutions and reasons for the purchase of materials. Although not a part of the NASA EDC program, including prices on items was introduced within the study to
help students realize the importance of cost and conservation of materials for potential future flights.

Once multiple solutions were drawn, the students in each group of four were asked to discuss their strategies and come to consensus on one drawing. The supply store was initiated to create the need to conserve products and reduce costs. Placing a financial constraint of $10,000 on the cost of items further complicated the design process for students, yet added to the realism of the task. Table 1 displays prices of materials that were available for use.

Table 1. Price list of items students were permitted to use.*

<table>
<thead>
<tr>
<th>Material</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Cardboard</td>
<td>$5,000 per sheet</td>
</tr>
<tr>
<td>White Cardboard</td>
<td>$5,000 per sheet</td>
</tr>
<tr>
<td>Aluminum Foil</td>
<td>$2,000 per 12 inches</td>
</tr>
<tr>
<td>Rubber Bands</td>
<td>$500 per rubber band</td>
</tr>
<tr>
<td>Mirrors</td>
<td>$250 small/$500 large</td>
</tr>
<tr>
<td>Tape</td>
<td>$1,000 per 6 inches</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Items (if in acceptable shape) were possible to be used again by other groups, and costs were partially refunded.

For students, the design process was the most difficult phase of the EDP. Each group spent approximately 10 minutes as students stated, “we want to go and test it out.” Throughout this period, the authors and classroom teacher posed questions to redirect students to the mathematics and science involved. The following exchange gives evidence of this point:

**Teacher:** So why do you think white paper will work better than black paper?

**Student:** Oh, that is easy. White will not absorb the light as much as the black paper.

**Teacher:** So which do you think is better, aluminum foil or white paper?

**Student 2:** Oh it has to be white paper. But wait, I see a lot of people with sun visors for their car made out of aluminum. So let’s go with aluminium.

**Teacher:** How much do you think you may need?

**Student 3:** Well the distance around has to be the circumference of the light bulb lamp, and then the length according to NASA has to be at least 20 cm high.

**Student 4:** We are making a cylinder. We need to find the lateral surface area.

Creating a Prototype

NASA’s *Powered and Pumped Up* manual defined a prototype as constructed based on the design model(s) and used to test the proposed solution. “A prototype can be a physical, computer, mathematical, or conceptual instantiation of the model that can be manipulated and tested” (NASA, 2018, p. 73).

Students created prototypes based on designs they drew on paper. Each team consisted of four students who assumed roles of resource manager, facilitator, recorder/reporter, and task manager. In creating a plan with an explanation, students were frustrated because of a lack of social skills necessary to work together. In only five groups out of 40 did students support each other as a team. Teachers reported that creating a prototype was the most difficult stage for students because they wanted to begin testing immediately upon drawing their designs or given the problem.

Students initially used black paper, aluminum foil, rubber bands, and rulers to create cylindrical shapes that would reflect the light in a way to maximize heat. Only twelve groups out of 40 described their plan to teachers in terms of the sequence of activities and who would perform each role. The classroom teachers used a graphic organizer with larger spaces to record steps and assist students in creating a prototype. Overall, students were anxious in advancing to the “testing” phase.

Testing and Evaluation

Evaluation includes drawing built upon mathematical and scientific concepts, brainstorming possible solutions, testing and critiquing models, redesigning, and refining the need or problem. Although students referred to this as “trial and error” they never returned to their drawings to change their design, and only one group restarted the entire process.

On the first day of the *Powered and Pumped Up* program challenge, students performed Investigation 1, “How Intense Are You?” This activity models the fact that the farther away from the sun an object is, the dimmer its light waves become and the harder it is to use its energy. Students used flashlights to investigate how much light waves spread as they travel through space. They centered their flashlight beam on a yellow dot on a centimeter ruler. Then students counted how many 1 cm squares were illuminated by the flashlight’s beam to find the diameter of the beam. Students then recorded their results on a data collection sheet as in Table 2.


<table>
<thead>
<tr>
<th>Flashlight Height</th>
<th>Diameter of Circle, cm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 cm</td>
<td>3 cm</td>
</tr>
<tr>
<td>8 cm</td>
<td>3.5 cm</td>
</tr>
<tr>
<td>12 cm</td>
<td>4 cm</td>
</tr>
<tr>
<td>16 cm</td>
<td>4.5 cm</td>
</tr>
<tr>
<td>20 cm</td>
<td>5 cm</td>
</tr>
</tbody>
</table>
“powered and pumped up” with NASA

Of the 40 groups, 38 created scatter plots and were able to predict the diameter of the reflection when the distances were 24 and 28 cm away, while two groups could not relate the data to the graph. Students commented that they now understood the purpose of scatterplots in making predictions (Figure 3).

**Student:** Oh so I can use the table and the graph to figure what comes next.

**Teacher:** What happens if we change the angle of the light?

**Student:** Well, let’s see.

**Teacher:** Simply record your results in your table.

**Student:** Naw, it is not right. It should be a right angle, that gives the best light. (Laughs at the use of “right”) I mean. That gives you the best light.

On the second day of the Powered and Pumped Up challenge, the teacher suggested that students create a chart of their results after noticing more haphazard trial and error. The teacher explained that while expert engineers test and retest, they do so in more intentional ways, such as recording their efforts and reflecting on their successes as well as their failures. Teachers used a chart and table for students to record results and review/review their work as shown in Table 3 similar to NASA’s EDC.

During testing and evaluation, students had difficulty calculating the percentage of change between time trials. Only 23% of students were able to calculate the percentage of change (given the formula). Many students had difficulty with substituting values into the formula. More pronounced were students’ difficulties with number sense represented by their lack of recognizing an impossible solution when they disregarded the order of operations. For example, if their baseline time was 15 seconds, and their second trial took 20 seconds, they found the percentage of change to be $\frac{20-15}{15} = 20-1 = 19%$ improvement.

**Research**

Research is an essential step within the engineering design process as well as in NASA’s challenges and one that provided teachers in the study with an opportunity to demonstrate the importance of finding credible sources while students used the information to support their decisions. Teachers obtained news

| Table 3. Template with a Sample Response of Student Testing and Evaluation Phase of EDP. |
|---------------------------------|---------------------------------|---------------------------------|
| **Test 1** (Original/ Baseline Result) | **Test 2** | **Test 3** |
| Time in seconds to pump 200 ml of water from one container to another. | 16 seconds | 12 | 14 |
| What conditions did you change? | ------------ | “We changed the angle of the lamp to be more directly over the paper.” | “We kept the angle the same. We put white paper around the light but did not have enough for the bottom.” |
| Calculate the Percent of Change. | ------------ | $\frac{(12-16)}{16} = - 25%$ decrease | $\frac{14-16}{16} = - 12.5%$ decrease |
articles on their own about the Mars Curiosity rover finding traces of organic material in a mudstone deposit in Mars’ Gale crater. Teachers asked students to read articles about this particular discovery and brainstorm researchable questions, which included:

- What organic materials did NASA find on Mars? How long was it there?
- Are there any other planets on which scientists have found water?
- How do we get oxygen on Mars?
- What is methane, and how does that make a difference?

Among the many sources, students used the History Channel and the New York Times as resources. In addition, during scheduled times, NASA allowed students to ask questions of scientists currently working on solar panels for the Mars mission. The following questions were developed by students in these classes and directed to NASA’s experts during a conference call:

- Do your experiments ever not work?
- Do you like what you are doing?
- How long did you have to go to school in order to work with NASA?
- How much math do you need to work at NASA?
- What happens if you break something?

A final question posed by the teachers baffled students, “Besides NASA, can you think of anyone else who could benefit from this problem being solved?” Perhaps since students have clean water available to them, their only response was to suggest that we can bring people to Mars and they would benefit. However, students never imagined that some parts of the world are without clean drinking and bathing water. One student then interjected: “Many of those countries have a lot of sun, maybe this will work there.”

**Conclusion**

The NASA engineering tasks proved to be an engaging experience that helped middle school students develop an understanding of the engineering process and a relevant application. By being actively involved in the process of designing, constructing, and testing a water-pumping device, students developed an understanding of the necessity of the steps within the engineering design process. Encountering obstacles during the construction process helped students to learn from their failures and rely on their peers. Many engineering projects for middle school-aged students cited in the literature (Hirsch, Berliner-Heyman, Carpinelli, & Kimmel, 2012; Robinson, Adelson, Kidd, Cunningham, 2018; Cunningham & Kelly, 2017) emphasize the interdisciplinary, project-based learning environment that draws on math, science, and technology and offers major benefits to students at all levels, as it fosters skills such as problem solving, communication, teamwork, independence, imagination, and creativity.

The NASA Engineering Design Challenge provided engagement for all middle school level students. It allowed for differentiation of student- and discipline-centered learning and provided challenging curriculum for all levels of students. All students were engaged because of their interest in the project and the amount of work to be completed. Because of this project, the University/K-12 School partnership implements all of the NASA engineering challenges throughout the middle school curriculum.

**NOTE: Appendices for this article are online at:**
www.iteea.org/TETMJ20NASA.aspx

**References**


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Introduction
Dutch researchers have developed technology whereby grass and other plants can generate electricity day or night. In this challenge, students and or teams can explore ways to utilize this technological advance and evaluate its impacts.

Researching the Technology
How does this technology work? It all starts with understanding the basics; as Thomas Edison would have said—how is the electricity produced? Students should first conduct research via the internet to understand how this technology works.

The potential output of this biomass is important to understanding what its electric-generation potential might be. One source estimated that 2.5 acres of grass can generate enough power for 24 homes or about 14 kW of power; and it can generate this power level for 24 hours. Knowing this, one can estimate the generation potential of certain plots of land; for instance, how much raw power can be generated on a:

- Residential home lawn
- Golf course
- City park
- Right of way...like for transmission lines
- Highway meridian
- School playing field
- Industrial park campus
- Other site(s)?
Could large plots of land such as golf courses, parks, and rights-of-way equipped with grass-to-energy systems become generating stations? Could empty lots and unused plots of land enjoy special incentives to be planted and become de facto energy production sites? Identify and discuss the following issues:

• Environmental
• Social
• Political
• Regulatory
• Legal
• Aesthetic issues that could come into play with this technology application.

Society might look differently at parkland if humans could play on it and also generate electricity using the grass. Identify the pros and cons of such a situation.

Think about how much energy the green areas around your school could generate and how this impacts the cost of traditional electricity for your school.

Let us suppose the grass is a very special kind of grass with limited application. How might it be worked beneficially into your town so humans and the grassland can coexist safely and beneficially?

How might this compare to the land needs of other popular sources of alternate energy like:

• Solar panels?
• Wind energy?
• Other?

Estimate what these already existing solar/wind technologies can generate compared to what the new biomass technologies could generate—on the same surface area of land—in this case 2.5 acres.

How would the power generation output be interfaced to homes, structures, or to the local utility system? Explore the potential safety issues involved with making these connections. Humans walk and play and recreate on grass. Their safety is an important issue.

Evaluate the costs of planting such grass; and, of course, “hooking it up” to generate electricity.

**Possible Impacts**

Can the new biomass be used anywhere we desire, or might it require certain conditions to thrive, grow, and generate electricity? Can the grass be cut and treated like any other grass we now use? How about the special plants—do they require special conditions for application?

What are the possible environmental impacts of the grass? Could it harbor pests and certain infestations that might transfer to other plants? Could it become a national problem like Kudzu has become in the southeastern regions of the U.S.?

If homeowners can generate their own electricity from their lawns, this can be a significant change to how we view the traditional functioning of the house. How might local municipalities view this from a safety code standpoint? Could the class speak with someone from the district/town who might be able to speak to this point? How might this impact landscaping around the home and the landscaping industry?

Like solar energy affected the nation's electric utilities, how might electricity-generating biomass impact traditional electric utilities? Might they manage the large land area applications, or perform maintenance and operating functions? How do you envision their role in the future?

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