Want a Complete Professional Development Experience in 2020? Add a Preconference Workshop to Your ITEEA Registration

ITEEA’s 82nd Annual Conference in Baltimore, MD - March 11-14, 2020

Part of creating a top-notch professional development experience for technology and engineering educators includes providing the opportunity for specially designed preconference workshops that delve more deeply into multiple topics. Workshops being offered on Wednesday, March 11, 2020 at ITEEA’s 82nd Annual Conference include:

**Design Thinking Crash Course**
This workshop will immerse you in human-centered design-thinking strategies through active learning. We will engage, experience, reflect, and discuss transferring design-thinking strategies to your classroom. Be ready for observations, interviews, “Point of View” statements, composite character profiles, and maybe, dancing. Participants will receive an exclusive sneak peek at the ITEEA Reach Challenge. Monday-morning-ready-approved. (1-4pm)

**Literacy Through the Lens of Technology: Librarians Supporting Literacy Through STEM Programs**
Librarians support print, media, and digital literacies, and now STEM has been added to the list. This three-hour workshop is designed for librarians who would like to collaborate with STEM educators in their building, district, and state. (1-4pm)

**Implementing Coding and Microcontrollers Through Hands-On STEM Applications**
*Hosted by TeacherGeek®* Increasing students’ ability to think computationally has become a nationwide initiative. Additionally, preparing students to design and think innovatively so they are better prepared for critical-shortage STEM careers has also been a focus. How can both of these initiatives be addressed to prepare a more technologically and engineering literate society? One solution is through cost-effective microcontrollers integrated within hands-on, content-rich STEM design challenges! Learn various ways to code the microcontrollers sold by TeacherGeek® and how to integrate them with TeacherGeek’s® fabrication materials to teach various science, engineering, and math concepts. The microcontrollers and TeacherGeek® materials are extremely user friendly, and this presentation will focus on applications for upper elementary through middle school settings (Grades 3-7). Correlating lesson plans, worksheets, and other standards-based instructional resources will be provided. Each participant will receive a microcontroller and TeacherGeek® fabrication materials. No prior coding or fabrication experience is required. (1-4pm)

**STEM in Elementary: Implementing a STEM Program in Elementary School**
Facilitated by award-winning elementary STEM professionals, this session will engage participants in discussing and designing school and classroom-tested strategies to engage students in STEM, integrate STEM into the school, and build school, home, and community connections through hands-on STEM-based activities. Participants will leave with strategies and at least one activity they can use to implement STEM in their classrooms. (4-7pm)
AN INNOVATIVE ADAPTIVE AND ASSISTIVE TECHNOLOGY CHALLENGE FOR MIDDLE SCHOOL, HIGH SCHOOL, AND COLLEGE STUDENTS

ITEEA’s Reach Challenge is an impactful design-thinking project for high school and college students, showcasing ITEEA’s mission that Technology and Engineering Bring STEM to Life!

Students will use their STEM skills to REACH a member of their community who has a challenge to overcome, and design a solution to help. Projects can then be submitted to ITEEA for an opportunity to earn awards and grant opportunities for your school!

With an Educators Toolkit, filled with lesson plans and activities, this innovative challenge shows students how they can use their STEM skills to make a difference in the lives of those around them.

“The Perfect STEM Project to Inspire Students…”

Learn more/sign up by November 1st! www.iteea.org/REACH.aspx or use the QR code.
DEVELOPING A STEAM PROGRAM FOR MIDDLE SCHOOL GIRLS THROUGH COMMUNITY COLLABORATIONS P.8
This article presents innovative strategies being successfully implemented in a middle school “Girls in STEAM Program.”
Ray Wu-Rorrer

USING ROLE MODELS TO INCREASE DIVERSITY IN STEM P.16
K-12 preparation for post-secondary STEM education is a long journey, and role models provide students with much-needed support and help to build self-confidence, an image in STEM, and interest in STEM along their journey.
Carrie Hutton

POPULATION AND TECHNOLOGY P.22
What has been the role of technology in the success of humans as a species? How has the interaction of technology and society influenced human population trends?
Vincent W. Childress

PREREGISTRATION FOR ITEEA’S 82ND ANNUAL CONFERENCE NOW OPEN!

Visit www.iteea.org/ITEEA_Conference_2020.aspx to reserve your spot for next year’s conference in Baltimore, MD—the world’s largest professional development and networking opportunity for technology and engineering educators!

PREREGISTRATION DEADLINE: FEBRUARY 14, 2020

DONT’ MISS THIS IMPORTANT DEADLINE!

DECEMBER 1, 2019

Application Deadline for ITEEA Scholarships and Awards

Are you an ITEEA member who is integrating a quality technology and engineering education program with the school curriculum? Are you a technology and engineering education teacher or supervisor who seeks professional development? Are you an undergraduate student majoring in technology and engineering education preparation? Are you a technology or engineering teacher who is continuing your education? Do you know of an exemplary teacher or program that you would like to nominate for one of ITEEA’s Professional Recognition Awards? If you answered “yes” to any of these questions, you should explore ITEEA’s grant, scholarship, and award opportunities at www.iteea.org/AwardsScholarships.aspx. These opportunities support the advancement of technological literacy.

NEWLY REDESIGNED AWARDS SECTION

ITEEA offers many awards and scholarships; to make it easier for our members to take advantage of these programs, we have redesigned our awards page. It has never been easier to apply, nominate, view award criteria, and more! Visit www.iteea.org/AwardsScholarships.aspx to see for yourself!

COMING SOON!

The brand-new ITEEA Member Experience, featuring a completely redesigned and easy-to-use eStore to renew membership, register for events, subscribe to journals, and more!
All professional articles in the ITEEA Headquarters staff.

official policy or the opinion of the association, its officers, or expressions of the authors and do not necessarily reflect the and engineering education.

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

EDITORIAL POLICY

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

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

REFeree POLICY

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

TO SUBMIT ARTICLES

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

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


TECHNOLOGY AND ENGINEERING TEACHER

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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.
Nominations Now Being Accepted for Salinger Award for Enhancing STEM Ed through Technological/Engineering Design-Based Instruction

This award is presented annually to an individual or team of collaborators whose work has exemplified, promoted, investigated, and/or enhanced teaching and learning in Science, Technology, Engineering, and Mathematics (STEM) through the effective application of technological/engineering design activity. The award was created in honor of Dr. Gerhard Salinger, program officer at the National Science Foundation from 1989 to 2014, whose work to promote the use of engineering design activity and whose advocacy for technology and engineering education has widely influenced STEM education. The award is open to classroom teachers, university educators, school administrators, and others whose contributions are consistent with the selection criteria. Deadline is December 27, 2019. Learn more at www.iteea.org/News/282/162383.aspx.

Upcoming STEMinar: Literacy Through the Lens of Technology

**Wednesday, November 6th @ 4:00 PM (EST)**

Librarians are asked to support a long list of literacies. Recently added to the list is STEM literacy—but it turns out to be a very effective match! This one-hour STEMinar is filled with ideas for librarians who would like to collaborate more with STEM educators in their building, district, and/or state. Learn more/register at www.iteea.org/STEMinar32.aspx. Free for ITEEA members.

Promotional Materials Available for Printing/Reposting

ITEEA has recently established an area on its website that will serve as a repository for downloadable promotional materials pertaining to ITEEA. With this new resource, affiliate newsletter editors and others can more easily include the materials in their publications. Additionally, conferences needing ITEEA-related flyers for projects such as the REACH Challenge or ITEEA Awards can download materials without having to make a request. Materials can be viewed/downloaded from www.iteea.org/News/162409.aspx.

ITEEA Author Donates Second Activity Book to Support ITEEA's Capital Campaign

Regular ITEEA contributor and author of the long-time “Classroom Challenge” feature in *Technology and Engineering Teacher*, Harry Roman, has released a new publication titled, "The Big Book of STEM Classroom Activities," as a follow up to his "100+ Activities to Bring STEM to Life for Classrooms and Student Project Teams." As a retired engineer and inventor, Harry likes teaching teachers, students, and school leaders about STEM and its applicability.

To support the important work of ITEEA's Foundation, Harry is providing BOTH of his newest publications to be downloaded at no cost to all - but asks that anyone who downloads consider making a donation to the ITEEA Foundation (www.iteea.org/capital_campaign.aspx).
developing STEAM programs for middle school girls through community collaborations

The "Girls in STEAM Program" focuses on combining internal resources and community collaborations to promote STEAM career exploration opportunities, with the goal of inspiring interest in STEAM careers.

Introduction

Creating strong community collaborations is a cornerstone in the success of career and technical education programs. Developing Science, Technology, Engineering, Arts, and Math (STEAM) programs for middle school students using community collaborations can be challenging. This article presents innovative strategies being successfully implemented in a middle school “Girls in STEAM Program” at Mary Ellen Henderson Middle School (MEHMS) during the 2017-2018 school year. The STEAM program at MEHMS focuses on combining school and community resources to promote career exploration opportunities and mentorships with the goal of inspiring long-term interest in STEAM-related careers.

Although short, these programs offer middle school girls an opportunity to explore new areas of interest in STEAM topics. They also provide long-term programs geared toward sustained groups of activities with the objective of “fostering creative thinking, problem solving, and real-world engineering simulations while encouraging and facilitat-

by
Ray Wu-Rorrer
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ing interaction amongst cohorts of female students in various stages of development” (Bayerle and Scanlon, 2017, p. 3). This principle has been the hallmark of the efforts by the teachers and administrators of Mary Ellen Henderson Middle School and the community initiatives by Falls Church City.

During Fall 2016, stakeholders came together to begin an initiative to significantly increase the STEAM offerings at MEHMS. Although the initiative was not originally geared towards Girls in STEAM, stakeholders believed that additional emphasis needed to be placed on offering programs for the female students at MEHMS based upon their various discussions during planning meetings. What has since transpired is an inspiring example of how quickly students can positively benefit when a school and its community join forces. The goal of this article is to share a few examples of how the Falls Church City community identified a need and worked productively to overcome barriers that hindered female students from pursuing college STEAM programs and STEAM-related jobs.

The middle school years are “an essential formative and transactional period for students to prepare for a fast-changing future and learn foundation skills for successful STEM careers” (Christensen, Knezek, Tyler-Wood and Gibson, 2014). Exposure to women role models in the sciences-, technology-, engineering-, and mathematics-related fields during their late elementary and middle school years can “positively impact the perspective of female middle school students and their preconceived notions about STEAM” (Stout, Dasgupta, Hunsinger, and McManus, 2011, p. 256).

Prior work suggests that informal mentorships may be a powerful way to trigger and maintain interest in STEAM (Ko, Hwa, Davis, and Yip, 2018). “Leveraging current research indicates that the presence of mentors and role models is instrumental to the recruitment and retention of females in engineering” (Bayerle and Scanlon, 2017). However, there is limited information and research about the proper formation of the informal mentor-

Rote and Smetana (2015) stated that students lean more towards mentorships versus guidance from parents, particularly during the middle school years, because adolescents tend to be more interested in developing identity with peers and other adults rather than with their own parents. Although the interactions with role models “will not necessarily inspire greater self-efficacy, careful selection of role models who can demonstrate success can more easily inspire a specific target group” (Codiroli & McMaster, 2017). According to Codiroli & McMaster (2017), it is “okay” to have “average” individuals currently working in STEAM professions serve as mentors in an effort to combat the myths that only extremely academically gifted people are suited for STEAM.

Over the years, many studies have aimed to identify exactly when perceptions of gender bias arise in the sciences (Wigfield et al., 1991; Blue & Gann, 2008; Miller, et al., 2006). Current evidence, however, suggests that early educational experiences are instrumental in being a catalyst for future involvement in science and technology (Milam, 2012). The middle school years are “important for improving girls' overall persistence in STEM fields, as most girls begin to lose interest in science and mathematics during early adolescence” (Christensen, Knezek, Tyler-Wood and Gibson, 2014).

The first efforts of the Girls in STEAM collaboration at MEHMS started in Spring 2017, with a locally based educational organization providing hands-on learning workshops as part of an after-school program for both boys and girls. These workshops were oriented toward being beneficial to both organizations. The school received specialized after-school programs, and the educational organization was able to pilot new programs prior to implementing them in their summer camp programs. Due to the successes of the first year, the committee reconvened in Fall 2017

Girls in CADD.
developing STEAM programs for middle school girls through community collaborations

to outline programs that could be offered during the 2017-2018 school year. The committee believed there was a need to offer additional “girls-only” workshops. Although the robotics, CADD, forensics, and medicine courses were open to both male and female students, the committee agreed to offer a special “girls-only” workshop focusing on robotics, with an additional emphasis placed on career awareness and planning as the capstone course for the year.

A second collaboration, which began in Fall 2017, focused on a joint effort between a locally based government construction contractor and Mary Ellen Henderson Middle School. The collaboration included opportunities for female speakers to talk with the students, a visit to the company’s headquarters, and a site visit to a defense agency project. It should be noted that many of the leading positions, such as contract manager, director of facilities, director of contracts, and director of operations, are females. The company takes great pride in its diversity and being the exception to the norm.

Collaborations

Envision is a leading experiential learning educational organization offering students an opportunity to explore their career and life interests. In alignment with its mission to help students make their career and life aspirations a reality, Envision’s support of the STEM initiatives at Mary Ellen Henderson Middle School (MEHMS) recently marked its third year. The objectives of this partnership have included the expansion and enhancing of existing STEM efforts, and the objectives of MEHMS faculty and administration provide Envision with a platform to strengthen its STEM curriculum through piloting its programs and strategies with the faculty, administration, and students of Mary Ellen Henderson Middle School.

The initial trial of workshops was completed in Spring 2017. Due to the success for the Envision/MEHMS partnership, Envision was able to develop and deliver an “Explore STEM” after-school program aligned with MEHMS extracurricular initiatives. Three focus areas were identified and included courses in forensics, medicine, and robotics while working to include makerspace activities. This provided a successful hands-on activity using Virtual Reality for the MEHMS Spring STEAM Night.

At the end of the 2017-2018 school year, Envision conducted a “girls-only” Explore STEM workshop focused on robotics. Fifteen girls participated in the three-week course. In the first course, “Introduction to VEX Robotics,” students were introduced to the VEX IQ kit, built basic models, and completed basic movements. The second week, “Introduction to Que Robotics,” focused on the Cue robotics platform, creating basic programming codes, and completing challenges using the various sensors and speakers on the Cue robots. The third and final week, “Introduction to Hummingbird,” allowed for the exploration of the Hummingbird robotics platform.

Markon Solutions, now in its 10th year of business, is a commercial construction contractor with 220 employees working on multiple Defense Agency projects. Starting in the fall of 2018 and continuing monthly throughout the school year, Markon Solutions will conduct theme-related workshops for all students after school in the school’s makerspace area.

During the 2018-2019 school year, Markon Solutions plans to visit each of the Grade 6 “Introduction to Technology” classes (10
### Table 1. Standards Addressed Through Girls in STEAM Programs

<table>
<thead>
<tr>
<th>Code</th>
<th>Grade</th>
<th>Standard</th>
<th>Benchmark</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>STL, 3F</td>
<td>6-8</td>
<td>Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.</td>
<td>Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.</td>
<td>Apply knowledge from other fields of study that have direct effect on the development of technological products and systems.</td>
</tr>
<tr>
<td>STL, 6D</td>
<td>6-8</td>
<td>Students will develop an understanding of the role of society in the development and use of technology.</td>
<td>Throughout history, new technologies have resulted from the demands, values, and interests of individuals, businesses, industries, and societies.</td>
<td>Demonstrate understanding of history of new technologies that have resulted from demands, values, and interests of individuals, businesses, industries, and societies.</td>
</tr>
<tr>
<td>STL, 9F</td>
<td></td>
<td>Students will develop an understanding of engineering design.</td>
<td>Design involves a set of steps, which can be performed in different sequences and repeated.</td>
<td>Design a set of steps to be performed in different sequences and repeated.</td>
</tr>
<tr>
<td>STL, 10C</td>
<td></td>
<td>Students will develop an understanding of the role of troubleshooting, research, and development, invention and innovation, and experimentation in problem solving.</td>
<td>Troubleshooting is a way of finding out why something does not work so that it can be fixed.</td>
<td>Research, plan, create, and evaluate multiple robotic missions for effectiveness.</td>
</tr>
<tr>
<td>STL, 10E</td>
<td></td>
<td>Students will develop an understanding of the role of troubleshooting, research, and development, invention and innovation, and experimentation in problem solving.</td>
<td>The process of experimentation, which is common in science, can also be used to solve technological problems.</td>
<td>Research, plan, create, and evaluate multiple robotic missions for effectiveness.</td>
</tr>
<tr>
<td>STL, 10F</td>
<td>6-8</td>
<td>Students will develop an understanding of the role of troubleshooting, research, and development, invention and innovation, and experimentation in problem solving.</td>
<td>Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system.</td>
<td>Research, plan, create, and evaluate multiple robotic missions for effectiveness.</td>
</tr>
<tr>
<td>STL, 11H</td>
<td>6-8</td>
<td>Students will develop abilities to apply the design process.</td>
<td>Apply a design process to solve problems in and beyond the laboratory/classroom.</td>
<td>Communicate with an expert in the field and share work with others.</td>
</tr>
<tr>
<td>STL, 11K</td>
<td>6-8</td>
<td>Students will develop abilities to apply the design process.</td>
<td>Test and evaluate the design in relation to preestablished requirements, such as criteria and constraints, and refine as needed.</td>
<td>Communicate the engineering design processes involved in the robotic design, including successes and failures.</td>
</tr>
<tr>
<td>STL, 16E</td>
<td></td>
<td>Students will develop an understanding of energy and power technologies.</td>
<td>Energy is the capacity to do work.</td>
<td>Apply electrical concepts to power and operate a robot.</td>
</tr>
<tr>
<td>STL, 16F</td>
<td></td>
<td>Students will develop an understanding of energy and power technologies.</td>
<td>Energy can be used to do work, using many processes.</td>
<td>Apply electrical concepts to power and operate a robot.</td>
</tr>
<tr>
<td>STL, 16G</td>
<td>6-8</td>
<td>Students will develop an understanding of energy and power technologies.</td>
<td>Power is the rate at which energy is converted from one form to another or transferred from one place to another, or that at which work is done.</td>
<td>Apply electrical concepts to power and operate a robot.</td>
</tr>
<tr>
<td>STL, 16H</td>
<td>6-8</td>
<td>Students will develop an understanding of energy and power technologies.</td>
<td>Power systems are used to drive and provide propulsion to other technological products and systems.</td>
<td>Apply integrated STEM concepts (e.g. experimentation, energy transfer, programming calculations).</td>
</tr>
<tr>
<td>STL, 18F</td>
<td>6-8</td>
<td>Students will develop an understanding of and be able to select and use transportation technologies.</td>
<td>Transporting people and goods involves a combination of individuals and vehicles.</td>
<td>Construct a plethora of robot models tailored to a specific challenge being presented.</td>
</tr>
<tr>
<td>STL, 18G</td>
<td>6-8</td>
<td>Students will develop an understanding of and be able to select and use transportation technologies.</td>
<td>Transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work efficiently.</td>
<td>Research and explore a conceptual theme, complete an engineering notebook, and construct a working robot.</td>
</tr>
</tbody>
</table>

developing STEAM programs for middle school girls through community collaborations

Table 2. Girls in STEAM Calendar of Events

<table>
<thead>
<tr>
<th>Month</th>
<th>Event Description</th>
<th>Grade 6 Only</th>
<th>Grade 7 Only</th>
<th>Grade 8 Only</th>
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<tbody>
<tr>
<td>September</td>
<td>Markon Solutions: Monthly Makerspace Mentoring Kickoff (Meet and Greet)</td>
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<td></td>
<td>Markon Solutions: Job Shadowing (Girls)</td>
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<tr>
<td>October</td>
<td>Markon Solutions: Monthly Makerspace Mentoring Physics (Air Rocket Challenge)</td>
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<td></td>
<td>Markon Solutions: Job Shadowing (Girls)</td>
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<tr>
<td>November</td>
<td>Markon Solutions: Monthly Makerspace Mentoring Arduinos (Circuitry and Programming Challenge)</td>
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<td></td>
<td>Envision: Explore STEM Course</td>
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<tr>
<td>December</td>
<td>Markon Solutions: Monthly Makerspace Mentoring Computer Science Week (Career Exploration)</td>
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<tr>
<td></td>
<td>Markon Solutions: Job Shadowing (Girls)</td>
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<tr>
<td>January</td>
<td>Markon Solutions: Monthly Makerspace Mentoring CADD Drawings (Design Challenge) / Envision: Explore STEM Course</td>
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<tr>
<td></td>
<td>Markon Solutions: Job Shadowing (Girls)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>February</td>
<td>Markon Solutions: Monthly Makerspace Mentoring Engineering Week (Engineering Challenges) / Envision: Explore STEM Course</td>
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<tr>
<td></td>
<td>Markon Solutions: Job Shadowing (Girls)</td>
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<tr>
<td>March</td>
<td>Markon Solutions: Monthly Makerspace Mentoring Pi Day (3/14 Math Activities) / Envision: Explore STEM Course / Envision: Science Fair / Markon Solutions: Science Fair</td>
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<tr>
<td></td>
<td>Markon Solutions: Job Shadowing (Girls)</td>
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<tr>
<td>April</td>
<td>Markon Solutions: Monthly Makerspace Mentoring Earth Day (Recycling Activities) / Markon Solutions: Career Fair / Envision: Career Fair</td>
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<tr>
<td></td>
<td>Markon Solutions: Job Shadowing (Girls)</td>
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<td></td>
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<tr>
<td>May</td>
<td>Markon Solutions: Monthly Makerspace Mentoring Star Wars (3D Printing)</td>
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<tr>
<td></td>
<td>Markon Solutions: Job Shadowing (Girls)</td>
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<td></td>
</tr>
<tr>
<td>June</td>
<td>Markon Solutions: Monthly Makerspace Mentoring Summer Planning (Mini Projects)</td>
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</tr>
</tbody>
</table>

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classes total) to discuss career pathways, the work they do, their impact, and how employees have selected career paths. Interested Grade 7 female students taking the computer applications course will be provided an opportunity to go to the Markon campus and “shadow” employees in small groups. During the Grade 8 year, two select groups of around 30 female students participated in a half-day field trip to one of Markon Solutions’ project sites and the Pentagon for the 2018-2019 school year. In addition to the monthly themed workshops and the grade-level-specific activities, Markon Solutions participates in the annual career fair, STEAM night, science fair judging, robotics team sponsors, and business day campaign projects.

Conclusion

Every female student needs an opportunity for success in STEAM. At Mary Ellen Henderson Middle School, a strong foundation has been built to enhance the community collaborations by allocating resources to further strengthen the focus and connections made during activities such as the annual career fair, the robotics programs, the makerspace, and the family STEAM night event. It is the hope of the author that the information within will provide some guidance in how to successfully implement a “girls-only” STEAM program, either as a stand-alone or in conjunction with existing after-school programs. The value of community collaborations and their need within educational settings benefit students and will positively impact society. As we prepare the next generation of students for STEAM careers, let us continue the dialog and efforts to further develop STEAM-related programs designed specifically for middle school girls, formulate plans for implementing long-term, sustained Girls In STEAM programs, and expand our lists of potential business and community partners in which collaborations are mutually beneficial.

References


Ray Wu-Rorrer, Ed.D., is a technology, engineering, and robotics educator at Mary Ellen Henderson Middle School and serves as the collaborative team leader of the career and technical education department for the Falls Church City Public School System (VA). He can be reached at wurorrer@fccps.org.

This is a refereed article.
What has been your secret to success as an educator and educational leader?

As an educator, I work to keep everything in perspective. Teaching is all about the kids—what they’re learning and what they’re experiencing and what they’ll take away. We are fortunate that our courses show students how school and the real world work together. We can have fun in our classrooms and still work hard and learn. It is also important to love what you do and care about your students. I make it a point to know something unique about each student that enables me to relate to them. As a teacher educator, I always tell my preservice teachers that their class can be the best vacation a student has ever taken or the worst, the choice is theirs and what they choose to do in the classroom. I want to take my students to Disney World. They may be tired at the end, but they will definitely remember some of the rides and hopefully the fireworks.

Whether you are a teacher or a teacher leader, you have to be willing to keep learning—that’s what is most important.

What lessons from your parents have you carried through the years?

My mom taught business math for almost 30 years, and my daddy was self-employed as a contractor. My mom taught me to teach with my heart, and my daddy taught me to work with my hands. I remember helping my mom wrap gifts for her students each Christmas and that she gave every student a candy bar and card on their birthday, which was not the norm in high school. I also remember her telling me about class projects—from determining
a mortgage payment and repayment plan to balancing a budget, she made math make sense and made it applicable. My daddy was not able to finish high school but was still the smartest man I knew. He could fix anything and always did. He overcame many obstacles as a child and some as an adult. He taught me the importance of doing things the right way. He showed me every day through his work and life how to solve various problems. He seemed to always be able to come up with a solution that would eventually work. My daddy could pick up an instrument and play it, pick up a tool and use it, or sit on a piece of equipment and maneuver it. School was not where he learned how to be successful and a man of his word; instead it was through his life experiences. He wanted me to have a better life and worked hard so I could have it.

What have you learned that you would want to pass on to younger generations?

Learning is not defined by your grades. Grades rest on a sheet of paper or in a computer. Learning is defined by your life experiences, and those exist in your heart. They define you and can move you to do great things.

• Love what you do and who you are doing it for.
• Always do the right thing; you will never regret it. You are the one who has to live with your decisions, so make the right ones.
• Everyone has something to contribute; you just have to be willing to listen.
• Take time to know your students for they represent our future.
• Encourage your students to be teachers. We need more teachers. Remember, the best teachers could even be your most challenging students who are just looking for an outlet.

How have you faced challenges specific to being a woman in a male-dominated field?

The obstacles that I have faced have been limited, and most were associated with ignorance. When I was inducted into Epsilon Pi Tau, I was asked by a longstanding member if I was the wife of another inductee. When I was pregnant, an administrator asked if I would prefer to be a stay-at-home mom. I have learned to take a lot of comments in jest and with a smile because, overall, those that I am closest to in the field and consider mentors have always been kind and respectful. However, I do find that I need to work harder to prove myself and my value to the field because of the ignorance of some.

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

When working with underrepresented populations, never forget what others bring to the field and classroom. Help underrepresented populations find their voice and be willing to listen to their perspectives. The voices of various underrepresented populations echo throughout our history and should be intentionally woven into our future if we hope to survive. I have always been taught that two are better than one. We should all keep this in mind as we work with one another.

What are you looking forward to next?

I am taking one day at a time and learning to enjoy life, my work, my friends, and my family. I feel that I should have a defining answer related to my career; however, I don’t at this point. I love that I am finally a full professor and the CTE Program Director at Appalachian State University and get to serve as the State Advisor and Executive Director for the North Carolina Technology Student Association. I have a wonderful husband, two girls who are actively involved in dance, church, and school, and a son at NC State. So, I am taking time to smell the roses while looking forward to what comes next.

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It is no secret that particular populations of Americans, specifically minorities, women, and students from high-poverty schools and districts, are underrepresented in Science, Technology, Engineering, and Mathematics (STEM) jobs (Presidents’ Council of Advisors on Science and Technology, 2010). In the 21st century, technology drives innovation and invention, and STEM is critical for American economic competitiveness, national security, and quality of life for all citizens (Dasgupta & Stout, 2014). The American workforce needs every capable STEM worker to keep America in a global leadership position. Research indicates that the underrepresentation of particular demographic groups in STEM careers contributes to the shortage of STEM workforce candidates and limits the extent to which members of the underrepresented groups can participate in lucrative, fast-growing careers (Malcom-Piqueux & Malcom, 2013).

Even if students do not intend to pursue a STEM career, they still need to be STEM literate to participate in the 21st century economy and workforce. American jobs require multidisciplinary problem-solving approaches that include technology in industries such as manufacturing, defense, health care, finance, government, weather forecasting, and even digital arts and music (Machi, 2009; Baron, 2015). Technology is evolving faster than ever before. To that end, technology standards have been developed by teachers and experts, under the direction of ITEEA, to...
define what every student in Grades K-12 should know in order to be considered technologically literate for the 21st century (ITEA/ITEEA, 2007).

ITEEA has been a strong advocate for the promotion of technological literacy for all students by supporting national technology standards in American classrooms. Teachers who use the standards for technological literacy spend less time on specific details and more time on concepts and principles, with the goal of producing students with a conceptual understanding they can use for years to come as technology evolves (ITEA/ITEEA, 2007). Students must be aware that technology is shaping the global society in ways that cannot yet be imagined. Technology solves problems, but it also creates new problems and challenges that must be addressed. Technology is taught independently in classrooms but is also used to teach other core subjects. The technology education standards are most evident in integrated, project-based STEM classrooms.

Students need role models to show them how to use technology to learn, how to use technology to meet a need, and how to use technology responsibly. Students need to be educated on the legal ramifications and liabilities of what they do online. They also need to be aware of the finality of posting information on social media sites and the internet at large. Technology is a significant part of everyday life and, like many other socially acceptable behaviors, students must have individuals who teach and model desired behaviors. All students use technology and deserve an education that includes training for safe and responsible usage. All students deserve an opportunity to participate in the 21st century workforce, which requires the integrated use of technology to solve complex problems.

Deliberately increasing diversity in the STEM workforce is a matter of equity and social justice. It is also imperative for meeting current and future workforce demands for STEM talent (Dorie, Jones, Pollock, & Cardella, 2014). Diverse groups of STEM professionals often find more creative solutions to problems than homogenous groups because of their different approaches to problem solving and unique experiences, both academic and personal (Knight, Mappen, & Knight, 2011). One way to ameliorate both the STEM workforce shortage and demographic under-representation problem is to better prepare all students to pursue postsecondary STEM education that leads to a STEM career. Frequent interaction with role models for at-risk students is a key component of K-12 STEM preparation.

Role models for students in K-12 education systems are not well defined. Role models are loosely described as persons from whom students want to acquire personal or professional attributes or knowledge (Benbassat, 2014). They can be parents, teachers, administrators, support staff at schools, industry, and community organizations. Ultimately, the more information role models have about STEM careers to share with students and their parents, the more accessible STEM careers become for all students.

A sense of belonging is associated with increased academic motivation and achievement, particularly in STEM courses (Savaria & Monteiro, 2017). A sense of belonging often accompanies joining a group or following a leader with similar characteristics to one’s own. When students have doubts about belonging in a STEM career, their academic achievement and engagement with STEM content is hindered, making them question whether their abilities, interests, and aspirations are compatible with STEM (Dasgupta & Stout, 2014). When students have the opportunity to interact and engage with successful STEM professionals who look like them or come from similar backgrounds, they begin to see themselves as successful STEM professionals, too.

When students do not have opportunities to connect with others like themselves, they tend to wonder whether they belong in a STEM career, making the lack of role models a significant reason some groups of students are underrepresented in STEM careers (Zimenoff, 2013). K-12 preparation for postsecondary STEM education is a long journey, and role models provide students with much-needed support and help to build self-confidence, an image in STEM, and interest in STEM along their journey. Role models also provide mentorship, which gives students a safety net to help them develop essential competencies and resilience (Marshall, et al., 2011). Risk, failure, and resilience are important components of STEM learning, and students need role models to demonstrate the required perseverance to succeed in STEM courses and careers (Morrell & Parker, 2015).

Early and persistent exposure to role models in a student’s K-12 education allows them to see and interact with individuals who have achieved positive outcomes in the STEM workforce, which can raise students’ self-efficacy and their belief that they can also achieve positive outcomes in a STEM profession (Institute for Broadening Participation, 2016). There are three primary pathways through which students can have regular interaction with role models: parents, teachers, and community members. Role models in each domain are critical to the development of academic behaviors, attitudes, interest, and self-efficacy needed to matriculate into a STEM career.

Parents

Children develop lasting attitudes about STEM at an early age. Dorie, et al. (2014) reported that children typically spend more than 80% of their waking hours outside of a school setting. Many of those hours are spent at home with parents, particularly before children begin their K-12 schooling. Parents’ attitudes about STEM, and how they encourage their children in STEM...
domains, impact the trajectory of their children's STEM interests and attitudes. From birth through the completion of K-12 schooling, parents serve as the most significant role models to which children have access.

Parents who are STEM professionals are likely to enhance their children's attitudes and interest in STEM fields more than parents who are not STEM professionals. Furthermore, households where one or both parents are STEM professionals typically have more financial resources to provide high-quality preschool care and programs for their children. A "parent in STEM" role model helps form students' belief that a career in STEM is realistic. Children understand their parents' careers more than any other career (Dorie et al., 2014). The challenge is underrepresentation in STEM careers, which leads to further underrepresentation by not having female and minority role models as parents in the homes of the next generation of untapped STEM talent.

Households without a parent in a STEM career need encouragement and access to information early and often during their child's K-12 education from STEM professionals who look like them or come from similar backgrounds. Parents' ability to dispel stereotypes about STEM fields—that they are too demanding, monotonous, solitary, or repetitive—will have a significant impact on their children. Changing a parent's perspective and attitude about STEM will directly impact their children's attitudes and interest about STEM. Parents do not need to know explicit information such as the specific differences between a mechanical engineer and an electrical engineer, a neurosurgeon and a cardiac surgeon, but they do need to be informed about basic information to foster and support their children's exploration of STEM careers (Keller & Whiston, 2008). One way to better inform parents about STEM careers and the academic path students need to take to matriculate is to engage them regularly during their child's K-12 education.

Parents must be supportive of school efforts, and that support begins with schools reaching out to parents to inform, encourage, and show receptivity to parents' input (Barton & Coley, 2009). Schools that support parental engagement are more likely to receive it than schools that discourage parental involvement. Parental involvement includes both academic and nonacademic awareness such as classroom activities, extracurricular opportunities, and coordination with teachers for interventions. Research has shown that parents of at-risk students may not know how to engage in their children's education (Museus et al., 2011). Schools can educate parents on how to effectively reinforce their children's interest in STEM occupations by encouraging related academic behaviors and learning, facilitating occupational mentorships for their children, and removing the uncertainty and barriers toward a STEM occupation (Moakler & Kim, 2014). Parents can only participate in a positive and encouraging way if they themselves are well informed and educated about STEM career pathways and the rigor and dedication required to prepare for STEM careers.

Teachers

All K-12 students' educational experiences are shaped by teacher quality (Palmer et al., 2010). Teachers are important role models in the STEM circuit. The National Science Foundation (2014) reported that teacher quality is one of the most important factors that influences students' learning, particularly in K-12 STEM classrooms. Students who explore STEM content and careers early and often in K-12 classrooms are more likely to develop an early interest in STEM than their peers who do not have the same quantity and frequency of STEM exploration (Lichtenberger & George-Jackson, 2013). As part of the STEM workforce shortage, STEM classrooms are too often staffed with good teachers who may not have the requisite STEM content knowledge to prepare their students for postsecondary STEM education. When teachers are unprepared, or underprepared, to teach STEM courses, they often use methods and techniques that are not effective. The result is that students find STEM content and future careers boring or too difficult, which leads to leaks in the STEM pipeline early in the K-12 circuit (Ritz, 2009; Wicklein, Smith, & Kim, 2009).

The more formal and informal interactions students have with good STEM teachers during their time in K-12 classrooms, the more accessible a future STEM career becomes. Students need to be exposed to knowledgeable and engaging teachers early and often in their education. Successful K-12 STEM classrooms require teachers who have a deep knowledge of STEM subjects and the pedagogy most effective for teaching the subject (Mason et al., 2011). Great STEM teachers also facilitate opportunities for students to interact with community partners both for short-term information-sharing sessions and long-term professional mentoring relationships. Teachers must be well prepared as role models to inspire the next generation of talent.

One way teachers with a limited STEM background can learn the content and pedagogy required to teach STEM courses is through professional development opportunities. The National Science Foundation (2014) stated, “Professional development enables teachers to update their knowledge, sharpen their skills, and acquire new teaching techniques, all of which may enhance the quality of teaching and learning” (p. 31). Professional Development opportunities can also increase the quantity of knowledgeable STEM teachers if it is implemented as a sustainable process and not a singular event.

Community Members

Partnerships with local industries, universities, museums, and mentoring programs can be developed in the classroom setting.
of role models who help underrepresented populations of students see and experience the application of STEM content and bring what they learn in the classroom to life. Role models can also help students connect what they do in the classroom to real-world jobs.

Conclusion

As American school systems march farther into the 21st century, the accessibility of role models, particularly in schools that serve large swaths of minority and low-income students, is disappearing. Students are not involved with community organizations, religious organizations, or after-school activities at the same rate they were even a decade ago, leaving them more isolated than ever before and devoid of opportunities to engage with role models who help them envision themselves in future careers. The impact role models have on K-12 students is not as easily measured as academic test scores, but is a significant part of developing interest, confidence, and academic behaviors that lead to a STEM career. Providing students with role models at home, in the classroom, and in the community is too often an overlooked but significant factor in how students see themselves as adults and how they connect what they do in K-12 classrooms with future careers. Perhaps increasing diversity in the STEM workforce begins with information and relationships developed early and often in the K-12 circuit via role models in a variety of domains.

Note: Article references are available online at: www.iteea.org/TETNov19MS.aspx

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This is a refereed article.
What do Nikola Tesla and Emily Dickinson have in common? They both observed the world closely and recorded their observations. One contributed to scientific and engineering knowledge, and the other to classic literature, but both started from a place of curiosity and contemplation. Like STEM (science, technology, engineering, and mathematics), poetry often involves a high level of abstraction in language and ideas, requiring specific critical thinking skills and promoting interaction. Educator Bernice Cullinan noted, “Scientists observe with a clear eye, record their observations in precise, descriptive language, and craft their expressions. Poets do the same thing.”

Infusing poetry into the STEM curriculum can serve to jump-start or introduce a topic, present examples of terminology or concepts, provide closure that is concept-rich, or extend a STEM topic further. Using poetry in STEM can show students how writers approach topics in very different and distinctive ways. In addition, students will see that they can learn a lot of information from a poem. Poetry has an advantage in that it typically consists of fewer words than expository prose passages and thus can be less intimidating to students who may be overwhelmed by longer prose and streams of new vocabulary, especially students acquiring English as a new language. We can introduce or reinforce a STEM topic with a poem in just a few minutes with language that is rich, vivid, and memorable and activities that are engaging and interactive.

When it comes to supporting STEM instruction, poetry offers these distinct advantages:

- Poetry is accessible to a wide range of reading abilities.
- The brief format of much poetry taps the essence of a subject.
- Poetry incorporates sensory language, giving students the sense of touching, tasting, smelling, hearing, and seeing.
- Poetry can make a topic memorable through the use of vivid imagery.
- Poetry can provide a vehicle for content presented through evocative language and rich vocabulary.
- Poetry can help students talk about issues that concern them.
- STEM + literacy instruction can merge through a one-minute poem.

Naturally, a single poem is not intended to be the entire STEM lesson, but it offers an innovative, engaging, vocabulary-full, and concept-rich way to launch or conclude a STEM lesson. STEM-learning expert Jill Castek (2013) challenged us to “break down those instructional silos” of STEM topics and literacy, and look for opportunities to maximize overlap among STEM and literacy. We need to ensure that vocabulary exposure is occurring in many contexts for maximum scaffolding and

by Sylvia Vardell and Janet Wong
STEM learning. Royce, Morgan, and Ansberry (2012) confirmed “studies have shown gains in literacy as well as science achievement in programs that blend science and literacy instruction” (p. 6). We can encourage students to think like a poet AND an engineer in observing the world around them, using all their senses, investigating how things work, and recording their observations in notes, reports, and even poems!

Here’s a sample poem to demonstrate how easy it is to make STEM and literacy connections. As you read the poem aloud, pantomime the actions by looking at a label, showing your shoes, and straightening items on the table. Then do a second reading by using the acrostic formula for this poem to invite students to say the first letter of each line while you read the rest of the poem aloud.

**Things to Do in Science Class**
by Laura Purdie Salas

Look at labels.
Ask advice.
Be sure to check directions twice! Wear

Solid shoes to shield your feet,
And keep your table clean and neat.
Follow rules that you are given.
Explore
The startling world
You live in.

Poem © 2014 Laura Purdie Salas from The Poetry Friday Anthology® for Science by Sylvia Vardell and Janet Wong (PomeloBooks.com); illustrations by Frank Ramspott.

Finally, this poem offers a teachable moment for talking about the importance of safety in STEM learning. Break down the poem and list and discuss all the safety issues included. Research your local safety standards and discuss with students the value of following directions, keeping the work area clean, wearing safety goggles/glasses, washing hands, and using tools/materials appropriately. Don’t stop there; look for additional STEM-themed poetry for more literacy connections. For example, you can find many more STEM poems in our book, The Poetry Friday Anthology for Science (2014). You can even collaborate to create your own poems to reflect your school system’s lab safety policies. In addition, you’ll find five key strategies to integrate poetry into your instruction in our “Observe, Explain, Connect” article (Vardell & Wong, 2014). Adding poetry to STEM instruction can take your teaching to the next level!

**References**


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Like their primitive ancestors, humans will often try to solve problems with applications of technology, through innovation or invention.

Introduction

With environmental changes, such as a warm climate becoming much cooler or a wet environment becoming much dryer, animals may have to adapt to survive. However, adaptation can take many generations. Adaptation occurs when a mutation in offspring creates an advantage. For example, if one of the offspring of a relatively bare mammal is born with thick fur, and the environment has become cold, that offspring is more likely to survive and reproduce, thus passing on its furriness trait to its own offspring. Its more-bare siblings might not have survived the cold before being able to reproduce. Adaptations allow the animal to better compete with other animals for the same resources. The giraffe is a classic example. During drought, when grass was sparse, animals that could reach and eat leaves survived another season while those that could not may have died off. Giraffes with longer necks survived to reproduce, passing on the long-neck trait. A plant’s or animal’s behavior may also allow it to have an advantage over competitors. If an environment changes for the long term, and it is no longer suitable for an animal that does not migrate, the population of that animal will decline. If the animal can learn to migrate, the species might be saved, and its numbers could eventually rebound after migrating to a more suitable environment.

Humans are no different when it comes to adaptations. Humans have
become the most dominant animal on the planet. They have adaptations providing advantages over other animals. They have even outcompeted other species in their own genus. Humans have opposable forefingers and thumbs for superior dexterity, very large brains for intelligence, walk upright with bipedal locomotion to cover distances more efficiently, care for each other in social groups, use language and symbolism (abstract thought), can control fire, construct shelter, and manufacture and use tools (including clothing and hunting tools). As of 2015, the worldwide human population was estimated at 7.38 billion (United Nations, 2017). But, with so many humans competing with other animals and plants, and each other, for the same resources, is such a large population sustainable? What will happen to other animals? What will happen to plants? What will happen to humans themselves?

Human Evolutionary Advantages

Scientists believe that Homo heidelbergensis evolved in Africa and was the first archaic human to migrate out of Africa. Homo heidelbergensis had a large brain case and more advanced stone and wooden tools, but still had a large face, strong jaw, and a rounded forehead with pronounced brow ridges. The species had the ability to craft and use better tools and take large animals. Scientists also believe it was the first hominid to build protective shelter, and it lived during a time when the Homo genus was known to first control fire. There is also evidence that members of family groups cared for each other during illnesses. All of these characteristics may explain why it was able to leave the temperate, food-rich environment of Africa (Smithsonian Institution, 2018a). The ability to migrate to the colder climates of western Asia and Europe would free it from competition with other hominids and allow it to prosper even with less plant food and with primarily hard-to-take, larger game.

Having evolved from Homo heidelbergensis, both Homo neanderthalensis (in Europe) and Homo sapiens (in Africa) inherited these important advantages. As Homo sapiens, with a very large brain, migrated to Europe, it was able to outcompete Homo neanderthalensis and drive the species to extinction. At this point in prehistory, humans started their march in earnest toward becoming the dominant animal on the planet. While both Neanderthals and humans were skilled tool makers, the former used thrusting spears and had to get close to a large animal to kill it, risking injury. Humans had throwing spears, spear throwers, and bow and arrow, so they faced less risk when taking large, dangerous game (Smithsonian Institution, 2018b). This difference in technology likely illustrates the types of differences that can explain why one was able to outcompete the other.

While other animals have been observed to fashion and use tools, humans have mastered technology. Even during prehistory, human technology was uniquely sophisticated and, along with brain size, is likely the principle characteristic allowing the human population to grow to 7.38 billion individuals over the past 300,000 years.

Environment and Climate

Based on the archaeological record, most hominids evolved in Africa, which generally provided easy forage. Early hominids picked fruit from trees and later, grains from grasslands, and while there were formidable predators, there was also easy-to-take small game and carcasses to scavenge. When climate and environment changes brought cycles of drought, bipedal locomotion became an advantage, allowing early hominids, like Homo erectus, to cover longer distances in less time compared to other primates. Homo erectus lived during the appearance of the hand ax, a milestone improvement in human technology (Smithsonian Institution, 2018c). Homo heidelbergensis, Homo erectus, and Homo sapiens may have competed when their presence in Africa overlapped and, with advanced tools, they had a competitive advantage over plants and other animals. As their ability to move, use tools, and take cover in shelter improved, they adapted to their environments. They could locate and take more nutritious food, thus warding off diseases and developing their large brains. Taking food more easily freed up time to develop more specialized tools, such as fish hooks, sewing needles, and clothing. As Homo heidelbergensis, Homo erectus, Homo floresiensis, and finally, Homo neanderthalensis disappeared from the fossil record, only Homo sapiens, with its very large brain, remained. It is likely that this brain enabled the development of its superior technology.

It’s difficult to estimate human population prior to modern census efforts, but genetic research determined that two African populations of the Homo genus lived apart for thousands of years in eastern and southern Africa. Researchers believe that sustained drought caused the populations to migrate apart. It is also theorized that a catastrophic volcanic eruption caused global climate change, killing thousands. About 70,000 years ago, after recovering from the catastrophic volcanic eruption, the population began to increase rapidly, coinciding with the exodus of hominids from Africa (National Geographic Society, 2008).

Because of its technology, Homo sapiens eventually inhabited every part of the world. They mastered warm and cold climates, forests and grasslands, mountains and plains, deserts, swamps, and ocean shores. They could take small and large game. It seems that each technological innovation created the advantage to create more innovations. They took game with sophisticated flake-tool spears and arrows. They cleaned and sewed hides for clothing. They stayed warm using clothes, fire, and shelter. But the population stopped growing because of a dramatic global cooling event.
population and technology

Permanent Agriculture and Civilization
Homo sapiens’ large brain and more sophisticated tools appear to have enabled it to outcompete all other species in its family. Around 10,000 BCE, with their adaptations and advantages well established, humans began to grow their food. They planted and harvested crops with primitive hoes made from deer antler and later copper, bronze, and iron, and they bred animals for milk and meat. The rise of permanent agriculture coincides with the thawing of a global cooling event and created a worldwide transition from hunting and gathering to construction of semipermanent and permanent settlements. It is estimated that the population began to grow from a base of about 5 million individuals (National Geographic, 2016). In most of the world, agriculture consisted of subsistence farming. Villages were small and made up of families that would support each other during conflicts with other villages.

The “Ice Man,” found mummified in the Alps in glacier melt, is an excellent example of how humans survived in Europe between the Neolithic Period and the Bronze Age, referred to as the Chalcolithic Period and overlapping with the Copper Age (about 3250 BCE). Among his tools were a leather quiver for arrows, two stone arrowheads, unfinished arrow shafts, a stone and wood dagger, a leather tote bag, a woven grass wrapping, and a copper ax with a wooden handle. Though the spinning of wool was a prolific technology by this time, the Iceman’s clothing was leather, fur, and thick grasses, perhaps because of his lifestyle. He even had a wooden frame for packing and hiking. He also carried fire tinder, some berries, and he had recently eaten domesticated wheat meal, peas, and lentils. He had a serious wound on his right hand that appears to have been inflicted some hours before he was finally mortally wounded by an arrow (Wierer et. al., 2018), perhaps for trespassing.

In river valley locations, very sophisticated civilizations arose in Egypt, Mesopotamia, India, and China. Annual flooding left the soil fertile, and farmers were able to grow surplus crops. This surplus allowed a division of labor and a medium of exchange to develop. Cities were established, and with these advancements came population growth.

Modern Population Patterns and Technology
Modern population growth follows a similar pattern to that of human emergence from the Neolithic Era, but exponentially (Figure 1). Several demographics are used to explain population. Fertility is the number of births per woman. Mortality is the number of deaths per 1,000 people. Life expectancy is the average age at death for people born in a particular cohort. Density is the number of people per kilometer. Population inertia is the change in population growth or decline that tends to continue despite other demographic changes. Changes in population tend to follow a pattern, moving from one region of the world to another (United Nations, 2017). Agrarian subsistence farming (modest family farms) gives way to industrial agriculture. The labor concentration shifts from agriculture to manufacturing, construction, and services (with urbanization); relative affluence improves access to adequate housing, nutrition, medical technology, sanitation, and education.

Medical technology. Less developed regions tend to have less access to technological innovations and resources. If the mortality rate is relatively high and life expectancy and population density are relatively low, the fertility rate tends to be high. Access to medical technology—medicines, vaccines, diagnostics, and surgery—improves mortality. As life expectancy increases, so does population. Generally, as access to medical advances improves life expectancy and infant mortality also improves, the population grows. As families realize improvements in life expectancy and infant mortality, the fertility rate begins to gradually decrease. However, the population continues to grow, because those children already born will still reproduce. Fertility rate reduction requires education, and when women are well educated, they gain access to effective family planning, can reconcile religious beliefs, and adjust their relationships with men (United Nations, 2017).

This cycle of population inertia has occurred in the Americas, Europe, and Asia, but not in Africa. While India will soon replace China as the most populated country, its rate of population growth, like most of the world’s population growth rate, is declin-
India's population inertia will have it top China soon. India and China have relatively high population density, while Africa has a relatively low population density. Between 1950 and 1955, the fertility rate in Africa was 6.5 children per woman, with relatively poor infant mortality and life expectancy. Currently, it has only dropped to 4.7 children per woman with significant improvements in infant mortality and life expectancy. In contrast, the fertility rate in Europe is 2.1 births per woman, a rate that will cause a population decline even with low infant mortality and high life expectancy (United Nations, 2017).

**Industry and agriculture.** The exponential world population increase coincides with the rise of modern industry and modern industrial agriculture. Figure 1 shows world population estimates for the past 2,000 years (Population Connection, 2016). View the American Chemical Society’s (2016) article on greenhouse gasses and compare the graph in Figure 1, here, to the second graph in the Society’s article showing how drastic increases in greenhouse gasses coincide with the Industrial Revolution and the rise of industry.

Growth in modern agricultural productivity, global trade, and transportation also coincide with exponential population growth. Primarily, the increased use of more efficient machinery, petrochemical fertilizer, and herbicides and insecticides causes this productivity growth. These factors have caused a decrease in land use and in labor costs. The increased production also lowers the cost of the crops for trade worldwide (Wang, Heisey, Schimmelpfennig, & Ball, 2015).

The Interaction of Humans and the Environment

Humans have outcompeted every animal and plant on the planet—so far. Humans have adapted well by using technology and their very large brains. And it looks like they are going to need to put those large brains to work. Current climate change is being caused by the warming effects of greenhouse gasses, primarily carbon dioxide, which is emitted by human activity. Carbon dioxide is produced when fossil fuels are burned. Humans use natural gas, petroleum, and coal to generate electricity, heat buildings, and cook food. They use gasoline and diesel fuel for transportation. The United Nations, in cooperation with its Intergovernmental Panel on Climate Change (2018), warns that if carbon dioxide emissions are not drastically reduced to a point that will limit global average warming to only 1.5°C, ecosystem destruction could be permanent, and the effects of the warming climate could be more acute than originally forecasted. The report estimates that limiting warming to 1.5°C would require a 45% reduction in carbon dioxide emissions by 2030, a huge reduction in the current global context. The U.S. is the second largest emitter of carbon dioxide and pulled out of the Paris Accord. This lack of cooperation by such a big polluter makes the goal of 1.5°C seem a long way off. But there are ways that humans can adapt to protect the environment. Many governments believe the real goal should be zero carbon dioxide emissions.

If countries abide by carbon emission reductions, the effect on the environment might not have catastrophic consequences. Unfortunately, a 2°C or higher increase in average global atmospheric temperature could have significant negative global consequences. It could produce enough thermal expansion in the oceans to cause widespread coastal flooding with costly losses and/or construction needed to adapt to the flooding. Ocean water could intrude into nearby aquifers, requiring expensive desalination or the expensive piping of potable water over long distances. If coastal residents get displaced, there would be unrecoverable real estate losses. Depending on where they live, displaced people might not be welcome to relocate. It is theorized that there could be drops in fish stocks and extinctions if regular ocean currents change and the oceanic ecosystem becomes imbalanced. Inland, as water sources begin to dry up, there could be more local and international water disputes. Crop failure could cause disputes over food. Overdependence on aquifers could cause fields to become salted with undiluted minerals that occur naturally in ground water. Gradual changes in flora could cause extinctions in both plants and animals. It is theorized that some animals could have reproductive failure. And, there could be widespread, long-term economic problems (Cockburn, 2018).
Like their primitive ancestors, humans will often try to solve problems with applications of technology, through innovation or invention. The technologies may have unexpected, negative consequences. When a solution is not well thought-out, it is referred to as a “technological fix,” implying that the engineer, business, or government is simply putting a Band-Aid on the problem without addressing the underlying cause. It is often easier to create a technology than to change a behavior. For example, with electrical power, it is relatively easy to switch a coal-fired power plant to natural gas. Natural gas produces much less carbon dioxide when it burns, but it still does, in fact, produce carbon dioxide. It is much harder to switch to alternative energy sources, such as wind and solar. Another example would be a coastal city building expensive walls to protect from flooding. Every technological solution has trade-offs. A region can switch to wind and solar, but the tradeoff is many more generating units, because wind and solar do not produce electrical power at the same level as a standard power plant generator. More land is needed for wind generator units and solar panel arrays.

With 7.38 billion people on the planet, it is no wonder that plant and animal habitats have been greatly reduced, pushing many species to extinction. For example, the North American red wolf has been reduced over the past 100 years to 40 individuals in the wild, all surrounded by human activity in a swamp refuge in North Carolina, reduced from an original range that included the eastern and southeastern U.S. Land is needed for humans to:

- Grow crops and livestock.
- Impound water for agriculture, industry, and drinking, cooking, bathing, and sewage.
- Mine minerals to supply manufacturing and construction.
- Harvest wood for manufacturing and construction.
- Drill for petroleum and natural gas to fuel transportation and generate electricity.
- Mine coal and uranium to generate electricity.
- Deploy solar arrays and wind generators for electricity.
- Construct landfills for waste disposal.
- Construct highways, airports, and shipping ports for travel and commerce.
- Construct dwellings and commercial and government buildings.

Is all of this sustainable? Of course not. It is not sustainable to have a human population of 10 billion by 2050, but there is not much chance to curb that rate by an amount that will make a significant difference. Population inertia is already moving that estimate forward. The consumption of land is not sustainable. The use of fossil fuels for energy is not sustainable. If climate change causes significant changes in habitats, more plants and animals will die. If climate change causes crop failure and drought, it’s possible that human conflict will escalate. But progress is being made. Installations of wind- and solar-generated electrical power are increasing; genetic engineering is producing drought-resistant crops, to name just two examples.

**Classroom STEM**

Humans are already making progress to reduce greenhouse gases by implementing more applications of alternative energy. What are the solutions to the problem of a warming climate? A very straightforward activity can help students understand the constructs of *technological fix* and *trade-offs*. Have students conduct research on the climate accord and work in groups to come up with solutions to the problem of reducing carbon dioxide emissions to zero by 2050. As a guide, have them address the following:

1. Based on what you know about *Homo sapiens*, explain the coincidence of population growth and industrial agriculture and industry in general.
2. How does the greenhouse effect cause climate change?
3. What are natural sources of greenhouse gases?
4. What are the technological sources of greenhouse gases caused by human activity?
5. What was decided in the Paris Accord?
6. What did the IPCC determine should be the primary goal for achieving global greenhouse gas reduction?
For each human-made source of greenhouse gasses:
7. Describe how the technology works.
8. Describe how many people would typically be affected. For example, the typical coal-fired power plant supplies power to ________ families.
9. Having listed all human-made sources of greenhouse gases, determine an alternative for each.
10. How could the alternative technology be scaled up for use around the world and serve the estimated 10 billion humans on the planet by 2050?
11. Describe how each alternative works.
12. Think through the consequences of each alternative. For example, would the alternative be able to replace the old technology in terms of the number of people it affects?
13. What are the trade-offs of each alternative?
14. Decide as a group whether or not each of your alternatives is a technological fix, and explain your reasons.

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Introduction

June 23, 1988 marked the beginning of a major shift in public discourse (Youra, 2019), national—and even international—debate (Sullivan, 2018; Vitali, 2017), and a movement that now dominates a large portion of modern culture (Blau, 2017). On that day, James Hansen of the NASA Goddard Space Institute gave testimony to the U.S. Senate Committee on Energy and Natural Resources regarding the phenomenon he described as “global warming” (Shabecoff, 1988). Hansen claimed that human activity, and its role in the greenhouse effect, was the cause of this warming (Shabecoff, 1988). The greenhouse effect occurs as the atmosphere traps heat radiating from earth toward space creating a sort of greenhouse where certain gases in the atmosphere block heat from escaping (NASA, 2019). While many of these gases (e.g., carbon dioxide) are necessary to sustain life, their presence has dramatically increased due to the burning of fossil fuels (U.S. Environmental Protection Agency, 2019a, 2019b). Thus, the consumption of fossil fuels, and the subsequent impact on the environment, has been of growing interest and concern for decades (England, 1994; Tverberg, 2012; Michieka, Fletcher, & Burnett, 2013; Zhang, 2011; Shafiee & Topal, 2009). Awareness has heightened as the World Health Organization has published that nearly 4.2 million premature deaths globally are attributed to ambient air pollution resulting from the burning of fossil fuels (World Health Organization, 2019).

One effort to reducing air pollution and global warming in recent years has centered on the replacement of fossil-fuel-burning vehicles with alternative energy options such as electric-powered transportation. In fact, electric vehicle technology is one of the fastest-growing, and ever-evolving, sectors of the energy industry (TR Fastenings, 2019). With the need to prepare the next generation of students with the knowledge and skills they need to work and thrive in the future, it seems there is no better time than now to bring electric vehicle technologies to the classroom.

by
Matthew Jones
and Scott R. Bartholomew
This article discusses how students can expand their knowledge and experience in alternative energy as they work in a technology and engineering education (TEE) setting to design, build, test, and race an electric go-kart. This lesson, which builds on the alternative energy movement, will provide students the opportunity to connect with core technology and engineering concepts and practices while creating innovative solutions for a global issue connected with transportation in the future.

The Electric Vehicle Movement

While much of the history of the automobile is centered on Ford’s Model T, the truth is that the automobile’s origins are found in the creation of electric vehicles. In very early 19th century Scotland, Robert Anderson, a Scottish inventor, was busy developing what was then called “the horseless carriage” (General Motors, 2010). It was a crudely made vehicle powered by nonrechargeable primary cells (Handy, 2011). Though sources are unclear as to the actual date, Anderson’s first drive around town in an electric car took place sometime between 1832 and 1839 (General Motors, 2010). Many engineers and inventors around the world sought to bring battery-powered vehicles to fruition by improving battery power and design, changing the weight of the vehicles, motor designs, and making batteries rechargeable (Handy, 2011). William Morrison of Des Moines, Iowa is credited for building the first successful electric automobile in the United States in 1891 (Handy, 2011). However, it was not until the mid- to late-1890s that electric taxicabs were common in the U.S. and throughout the world.

The first speed record recorded for an automobile was completed on December 18, 1898 in an electric vehicle (Gertz & Grenier, 2019). Count Gaston de Chasseloup-Laubat of Paris, France, became the fastest man alive by driving an unprecedented 39 miles per hour (mph). The following year, the tenacious Camille Jenatzy of Belgium broke the land speed record, going 65.79 mph in his torpedo-shaped electric car named, La Jamais Contente, or “The Never Satisfied” (Figure 1; Gertz & Grenier, 2019; Handy, 2011). However, it was not until the mid- to late-1890s that electric taxicabs were common in the U.S. and throughout the world.

Go-Kart Racing: Gasoline- and Electric-Powered

The high cost of a new automobile has led many would-be motorists over the decades to tinker around and find ways to work with vehicles on tight budgets. In 1957, in Pasadena, California, one group started an event in the Rose Bowl stadium parking lot (Boberick, 1998; Pole Position Raceway, 2012). It consisted of small, one-man vehicles with light frames made from tubular steel, a primitive-looking open seat, and a small gasoline engine mounted behind the driver (National Museum of American History, 2019). Grown men raced the small vehicles around the parking lot with enthusiasm. These four men would go on to shape what we know today as “go-karting” or “karting.”

The creator of the first go-kart was Art Ingels in 1956. Duffy Liv-
In 1957, Ingels and his business partner Roy Desbrow joined Art with their own go-kart, called the “Drone,” thus named because it was equipped with a 250cc engine acquired from an old U.S. Army radio-controlled drone airplane (Boberick, 1998). The fourth man was Don Boberick, who joined as the official driver of the “Drone” in the race (Figure 2). Those rickety, exhilarating laps on the dirt convinced Boberick that this sort of racing should be enjoyed across the country. He went on to found the Go Kart Club of America in 1958 (Boberick, 1998). That same year Roy Desbrow and Duffy Livingstone started Go Kart Manufacturing Co., where they engineered and sold one-off, two-stroke versions of Ingels’ earlier go-kart design (Pole Position Raceway, 2012). Soon, go-karts were being made and raced throughout the U.S. (National Museum of American History, 2019).

Livingstone and Desbrow originally intended go-karting for pre-teens and teens; however, the sport has grown to include adults as well. Competitive go-karting, through the years, has become a starting ground for would-be professional race car drivers. Notably, NASCAR’s Jeff Gordon, “Indy 500” drivers Al Unser, Jr. and Michael Andretti, and European “Formula-1” drivers were all champion kart drivers as preteens (National Museum of American History, 2019). Today karting, with both gas-powered and electric-motor options, has roared through countries around the world as an exciting sport and an educational platform for STEM concepts (Figure 3).

**Technology and Engineering Classroom Connections**

The authors present a lesson plan that challenges students to expand their knowledge and experience in alternative energy as they work to design, build, test, and race a mini electric go-kart. While many high school programs cannot afford a full-size kart to facilitate learning of skills related to electrical vehicle enterprise, electric karts—both full-size and model—may facilitate this experience.

These electric karts provide opportunities for teachers to engage students in many fields of study, including electronics, physics, technology and engineering, innovation and human-centered design, manufacturing engineering, metals and polymers, mathematics (algebra, geometry, and even basic statistics), and other content areas with real-world, hands-on applications.

**Conclusion**

The educational system strives to help the rising generation gain the knowledge and skills to participate as contributing citizens and working members of society. We can best accomplish this purpose as teachers through socially relevant curriculum for our students. Our desire to bring electric go-karts to the high school classroom has been part of this effort. Electric mobility, the quiet origins of our automotive history, plays a large part in the marketplace as the world seeks to minimize global climate change due to overconsumption and misuse of fossil fuels. Teachers can provide a front-row seat to this enterprise for their students with the introduction of electric go-karts in their classrooms. An electric go-kart combines such an array of valuable skills and knowledge, with accommodations for diverse levels of competency and usability, that it is not hard to see the positive impact that it can have in the lives of our students as they prepare for the uncertain but inevitable future. At the very least, an electric go-kart in any STEM classroom will provide students with a tangible and ready answer for the question, “When am I ever going to use this knowledge?”

**Additional Resources Available Online:**
Daily Activities
Bike Seat Challenge Worksheet
Fossil Fuels and Electric Vehicles Worksheet
Mini Kart Design Checklist
SCAMPER Activity Worksheet

www.iteea.org/TETNov19SRC.aspx
References


The authors would like to thank the Indiana Manufacturing Competitiveness Center (IN-Mac; www.purdue.edu/in-mac/) for their generous support of this project. All rights reserved. IN-Mac 2019.

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### Lesson Plan: Exploring Alternative Energy Through Electric Vehicle Racing

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<thead>
<tr>
<th>Exploring Alternative Energy Through Electric Vehicle Racing</th>
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<td><strong>Time:</strong> 360 minutes (3-4 90-minute class periods)</td>
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**Lesson Purpose:** Students will learn about an Engineering Design Process by participating in two engineering design challenges. The first design challenge will give students an opportunity to experience the importance of a human-centered approach to design in technology and engineering. During the second design challenge, students will sketch several mini-kart chassis in preparation for 3-D printing. Using a checklist of final functional requirements for the mini-kart chassis, students will assess their sketches’ accuracy and effectiveness in meeting those design requirements. Students will also be introduced to the mindset of human-centered design, as this is a major skill for 21st century engineers and designers to acquire and apply. Students will participate in the iterative nature of this process of design to help them gain a sense of the role this process plays in industry.

**Global or Local Issue:** In this lesson students will engage in activities and topics related to the grand engineering challenge of restoring and improving urban infrastructure. Specifically, students will learn about the importance of alternative energy sources for transportation systems as we strive to decrease the carbon footprint. Student teams will design a chassis for a mini-kart that can set the foundation for further studies in vehicular design and electric mobility.

**Connected STEM Standards:**

- **Standards for Technological Literacy:**
  - Standard 5 - Students will develop an understanding of the effects of technology on the environment.
  - Standard 9 - Students will develop an understanding of engineering design.
  - Standard 11- Students will develop abilities to apply the design process.

- **Next Generation Science Standards:**
  - HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**Student Outcomes:**

- Students will be able to apply the engineering design process to solve a variety of problems within the scope of transportation technology.
- Students will be able to construct an argument related to electric vehicles and their impact on the environment.
- Students will use a final checklist of functional requirements for the mini-kart chassis and a paper cutout of their design to test the general size of their chassis design.

**Enduring Understandings:**

- How to view engineering design problems from the standpoint of the human experience.
- How to apply the engineering design process to technological problems.
- How to build upon iterative knowledge and experience to enhance learning and application.

**Driving Questions:**

- **Engage:** What can I do to train myself to look at problems from multiple points of view and therefore find the problem's human experience or essence?
- **Explore:** What effects do fossil fuels have in our atmosphere, and how do electric vehicles play a part in solving rising carbon levels?
- **Explain:** What is the engineering design process and how do I apply it?
- **Engineer:** What are various ways to design a mini-kart chassis?
- **Evaluate:** Do my chassis designs allow for all of the necessary components to fit on the mini-kart and function properly?

**Career Connections:**

Students throughout this lesson will learn critical skills related to human-centered approaches to engineering design and competencies in an iterative design process. These skills will benefit students in all fields within technology and engineering and will apply to broader career and occupational pathways such as: Manufacturing, UX Design, Electrical Engineering, Design Computer Engineering, Mechanical Engineering, Programming, and Computer Science.

**Supplies:**

- White paper
- Graph paper
- Scissors
- Rulers
- 3-D printer and filament
- CAD software
Engineering promotes problem-solving and project-based learning, makes mathematics and science relevant to students, enhances technological literacy, and helps students better navigate a three-dimensional world. As a noncontent area for K-12 education, however, engineering and engineering design are not often intentionally taught in many classrooms—or outside of them at the moment. To combat this disparaging situation, initiatives such as *The Next Generation Science Standards* (NGSS, 2013) have created new demand and opportunity for teacher professional development and student exposure to the engineering design process through systems thinking approaches and an emphasis on STEM influences on society and the natural world. These opportunities are ripe for both formal and nonformal learning arenas right now.

Engineering need not be a core content area, but rather it should act as the integrative bridge between noncohesive subjects, particularly within STEM education. This bridge can occur inside and outside the classroom.

**Implementation**

Approximately 95% of learning throughout a person’s life occurs in out-of-school, nonformal settings such as organized programming, hobbies, museums, television, and other sources, with only 5% of learning occurring in the traditional classroom (Falk & Dierking, 2010). Application of content can be showcased in a variety of...
avenues, though a strong development of practical know-how is often learned through “doing” (Fenwick, 2003). Nonformal programs challenge students to utilize their minds and hands to solve engineering design problems through connections with real-world collaborations (NRC, 2009; Worker and Mahacek, 2013), therefore offering a platform for experiential learning, which increases options and choices for learners to engage with their individual passions (Worker and Mahacek, 2013).

Nonformal learning opportunities expose students to engineering design and encourage creativity, innovation, communication, and collaboration, which can translate back to the classroom content. One prevalent challenge, as engineering continues to develop in both formal and nonformal K-12 settings, is that educators need to think past common applications such as traditionally accepted bridge building, robotics, and rocketry. This acknowledgment will offer students with interests in other areas the opportunity to see alternate uses for inquiry and problem-solving. In order to encourage this broader approach to engineering, this lesson expands upon the technical instructions manual accompanying technologies such as the Bio-Rad Vertical Electrophoresis System™ to include a variety of applications and inquiries that will encourage students to explore STEM in a wider context. While an excerpt of this unit is shared within this article, the full lesson plan, including specific steps and guided inquiry questions, can be found at http://bit.do/biotechinabox.

The Challenge

By utilizing the 5 E’s model (Engage, Explore, Explain, Elaborate, Evaluate) based on the constructivist learning theory (University of Maryland Extension, 2017), educators can help students build upon their current understanding in formal classroom contexts. It is common for students to lack the ability to make these connections on their own, therefore requiring the assistance of an educator to clearly define the relationships between these content areas (Agustin, et al., 2012; Heibert & Lefevre, 1986). Through the 5 E model, youth can learn new topics, build content skills, and develop designs and elements that project into future interests. This experiential learning model involves the youth in a hands-on activity, critically accesses the lesson, encourages students to reflect on important concepts and finally utilize this information in future activities.

During the Engage portion, educators should introduce the students to the content area with questions or events that create connections to what students already know or are able to do. This frames the ideas of the activity and introduces interest, particularly in nonformal settings where students have likely engaged with material previously in a variety of ways.

In the Explore stage, utilized twice in this specific BioRad lesson plan, students work together to brainstorm and develop questions and skills embedded in the unit. For example, students might brainstorm questions to be answered during the activity by comparing and contrasting previous experiences. Students might also engage with a common experience that allows them to clarify and deepen their current understanding of major topics.

With the Explain sections, again two utilized in this plan, students build upon the hands-on activities—including processes and concepts—they explored. With the assistance of the educa-
tors, students construct reasons and justifications for what they observed (or did not observe) in the activities. These can range from guiding questions resulting from brainstorming or various forms of communication that further develop skills and ideas.

The Elaborate portion challenges the students to apply their new concepts and understandings to further situations. This extension of knowledge builds upon the activity and reflection of the concepts and processes through real-world applications or horizontal/vertical utilizations.

Finally, students Evaluate their learning—through both knowledge and skills. In nonformal activities, a summative evaluation may not be effective as the students see minimal motivation to succeed, though fun and engaging evaluations such as trivia rounds can be utilized. Instead, nonformal lesson plans should intentionally integrate formative evaluation throughout all sections of the activity. This constant feedback and assessment of learning also allow educators to gauge understanding and tailor question and engagement levels.

Summary

While some might argue that lessons such as this cater towards nonformal education, teachers should not be deterred from integrating these lessons into their formal classrooms. Nonformal lesson plans—including their structures and techniques—can and should be integrated into formal classroom settings. Many nonformal activities are easy to integrate into broader unit activities and can even act as the expanded, real-world application to many of the more abstract STEM concepts. Additionally, nonformal activities often include ready-to-use, hands-on components that might otherwise be left out of some formal curriculum.

Educators should consider connecting with their land grant universities to determine if their outreach programs might offer the material resources necessary for these activities; for example, Virginia Tech offers access to the Bio-Rad Vertical Electrophoresis System™ free of charge for Virginia teachers.

Note: A Lesson Overview and detailed Lesson Plan are available online at: www.iteea.org/TETNov19DBL.aspx

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Introduction

Fuel cells are a fascinating and promising way to produce electricity from a very clean fuel form, hydrogen. These battery-like systems can operate efficiently using natural gas as a raw fuel input. Equipped with a fuel preprocessor, a fuel cell can strip off the hydrogen from the natural gas hydrocarbon fuel and use that hydrogen to make clean electricity, with very little in the way of emissions except for some waste heat, water, and carbon dioxide. Fuel cells have been touted as the next generation car engine to eventually replace the venerable internal combustion engine. In this challenge, students will investigate the use of a fuel cell for heating and cooling a home and also making its electricity right on site. The subject of fuel cells should fit in nicely with any educational units you are doing on green or alternate energy technologies.
The Challenge

Students first must learn about fuel cells, using the plethora of information available on the Internet, so encourage them to get busy and understand how fuel cells operate, where they have been applied before, and if engineers have tried to use them in homes as well. It would also be good to have students comprehend the history of fuel cells, how they got their real start in the nation’s space program, and how they are being considered for use today. Perhaps your students could list the various applications already tried and what kinds of success were achieved.

Make a list of the kinds of concerns involved with using a fuel cell in a home heating/cooling/electricity application. Some concerns to get this list started might be:

1. What size fuel cell would be needed for a typical home?
2. Where to locate the fuel cell in the home.
3. Availability of natural gas in the home.
4. Alternate fuels that could be used.
5. Connecting the fuel cell’s heat output to the existing heating system.
6. How to connect the fuel cell to the home’s electrical system.
7. Safety with the use of hydrogen in the home.
8. Other?

Spend some time having students develop one-line diagrams showing how the fuel cell would link up with the home heating system and the electrical system of the home. These schematics should provide some insight into how the fuel cell can be integrated into the home’s existing systems. Encourage students to think about their own home and how this might be accomplished.

Could there be concerns with the incoming natural gas line in the house? Is it large enough to support the energy input needs of the fuel cell? Would there still be a need for the existing home heating system? How does one get the air conditioning? Are all existing heating systems in homes easily interfaced to a fuel cell?

What are the probable dimensions of the fuel cell and its supporting equipment? Think about how such dimensions might be accommodated in, for example, an existing home basement. Assume a typical basement size of 40 by 40 feet, with a natural gas pipe entering on the north side of the house and electrical panel for the home on the opposite southern wall. Where is the best place to locate the fuel cell? Assume the existing chimney of the home is on the west side of the house where the existing heating system is. How might students locate and link up the systems? Perhaps some paper models of this scenario can be made, and students could try different options for locating the fuel cell.

Considering the variables with a fuel cell installation, have your students attempt to develop some approximations for what it might cost to install a fuel cell system. Compare this to existing home heating systems and the cost of electricity from the local utility.

Is it possible that a fuel cell system could operate like a solar system that makes electricity from panels on the roof, where excess electricity generated could be sold back to the local utility grid? How might this work?

Evaluate the local codes and building regulations in your town/city/municipality. Do they allow for a fuel cell installation? If not, what does this mean for someone who wants to install such a system? What kinds of issues would a building inspector concern himself with for a fuel cell installation? Check the literature to see if these issues have been dealt with or discussed before. Is there a history of experience with fuel cell technology?

Contact your local electric and gas utilities and get their input as well. They may be able to supply a speaker to your classroom to discuss fuel cell technology. They may already have experimented with them.

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