VOLUME 81 ISSUE 3

technology and engineering TEACHER

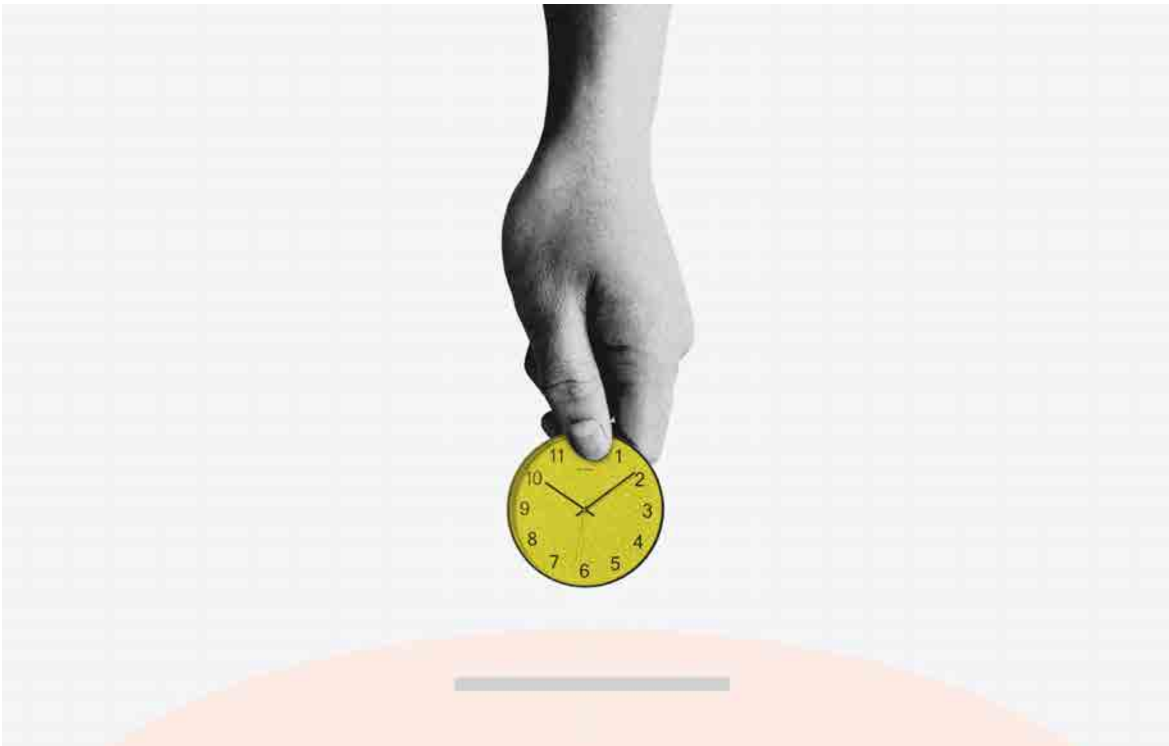
November 2021

EXPLORING THE EDGE OF SPACE

www.iteea.org

ITEEA's 84th Annual Conference:

EARLY-BIRD PREREGISTRATION NOW OPEN!



Register by December 1 for ***Additional Savings*** on ITEEA's 2022 Conference
March 9-12, 2022 in Orlando, Florida

Attend Face-to-Face or Virtually!

The ITEEA 2022 Orlando Conference offers:

- Over 100 peer-reviewed special interest sessions
- A series of hands-on workshops
- Go Baby Go! Dream Ride Event
- Keynote speakers
- A busy exhibit floor, including vendor Action Labs
- Field Trips to Kennedy Space Center
- ITEEA's STEM Showcase
- EbDLabs
- And more!

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

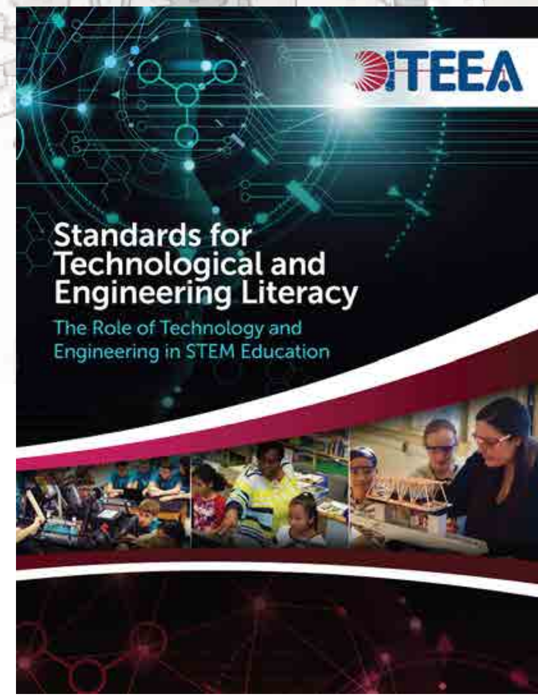
Preregistration provides many benefits, including saving TIME and MONEY as well as eligibility to win a $100 gift card.

ITEEA orlando March 9-12, 2022

Early-Bird Registration is Now Open!
For the latest conference information, go to www.iteea.org/ITEEA2022.aspx

Standards for Technological and Engineering Literacy is here!

What ALL students should know and be able to do in order to be technologically and engineering literate.



Standards for Technological and Engineering Literacy (STEL) provides an up-to-date roadmap for classroom teachers, district supervisors, administrators, states, and curriculum developers to promote technology and engineering education program development and curriculum design from Pre-K through twelfth grade.

The universals of technology have changed since the original *Standards for Technological Literacy* was published in 2000. The 2006 *Rationale and Structure* document and relevant literature published since *STL* was released were used to inform the current revision project. This update includes reducing the number of standards and benchmarks and adding new content such as crosscutting concepts to mirror the practices of contemporary standards developed for other disciplines.

The document is now available in print, ePub, and PDF formats and will soon be part of a dedicated interactive website, including curriculum development resources.

STEL is available on the following formats at www.iteea.org/STEL.aspx:

As a viewable PDF (FREE)

As downloadable/printable PDF
(FREE for ITEEA Members/$25 for Nonmembers)

As an EPub
(FREE for ITEEA Members/$25 for Nonmembers)

As a printed publication.
Members: $27/Nonmembers: $38
*Shipping fees apply

For more information, visit the *STEL* webpage at www.iteea.org/STEL.aspx.

This work was made possible through grants from the National Science Foundation and the Technical Foundation of America.

ITEEA
Technology and Engineering bring STEM to Life!
International Technology and Engineering Educators Association
iteea.org

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On the cover: *A zero-pressure balloon designed and constructed by student interns is being filled with helium for flight.*

on the iteea website

Important ITEEA Council Information Updates

ITEEA Councils provide a beneficial way to work directly with other members who share a great deal in common professionally. Being part of a Council provides additional professional resources as well as networking and leadership opportunities. Joining a Council has never been easier. ITEEA has updated each of its Council pages, which are accessible at www.iteea.org/40079.aspx. Each Council's subpages have been updated and information on how to join Councils has been added and streamlined.

Additionally, in anticipation of the upcoming ITEEA 2022 Conference in March, all Council-related programming has been added to the Conference Programming page at www.iteea.org/196248.aspx. See what Council-specific topics will be available in Orlando!

CTETE

Council on Technology and Engineering Teacher Education

Council on Technology & Engineering Teacher Education (CTETE) provides leadership to colleges/universities in the areas of standards, research, and professional interests related to higher education.

CSL

Council for Supervision and Leadership

Council for Supervision and Leadership and Administrators (CSL) provides leadership to technology education coordinators and administrators, assists in curriculum development, promotes model programs, and provides teacher inservice. Dues include forum discussions and other publications on supervision and administration.

ESC

The Elementary STEM Council

The Elementary STEM Council (ESC) promotes technology education in the elementary school by supporting teachers with instructional materials and inservice monographs, workshops and technology activity curriculum packages. Dues include a subscription to The Elementary STEM Journal.

TEECA

Technology and Engineering Education Collegiate Association

Technology and Engineering Education Collegiate Association (TEECA) consists of undergraduate student organization chapters and individual memberships. By joining ITEEA, student members are automatically members of TEECA at no additional charge.

technology and engineering TEACHER

International Technology and Engineering Educators Association

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stem education calendar

ITEEA Orlando
March 9-12, 2022

March 9-12, 2022

SAVE THE DATE!

for ITEEA's 84th Annual Conference!

November 5-7, 2021
ITEEA Authorized Training Institute (ATI)
www.iteea.org/ati.aspx

November 18, 2021
6:00pm EDT
ITEEA's Roundtable Discussion Series
ITEEA's Elementary STEM Council
FREE TO ALL!
www.iteea.org/roundtable.aspx

December 1, 2021
Deadline for Early-bird Conference Registration and ITEEA Awards and Scholarships
www.iteea.org/awardsscholarships.aspx

December 8, 2021
7:00pm EDT
ITEEA's Roundtable Discussion Series
Cultivating Creativity in the Classroom
FREE TO ALL!
www.iteea.org/roundtable.aspx

January 19, 2022
7:00pm EDT
ITEEA's Roundtable Discussion Series
Recruiting and Retaining Girls in the T&E Classroom
FREE TO ALL!
www.iteea.org/roundtable.aspx

February 16, 2022
6:00pm EDT
ITEEA's Roundtable Discussion Series
Teaching Sustainability Education
FREE TO ALL!
www.iteea.org/roundtable.aspx

March 9-12, 2022
ITEEA 84th Annual Conference
Caribe Royale All-Suite Hotel and Convention Center
Orlando, FL
www.iteea.org/ITEEA2022.aspx

April 13, 2022
7:00pm EDT
ITEEA's Roundtable Discussion Series
Recruitment, Retention, and Diversity
FREE TO ALL!
www.iteea.org/roundtable.aspx

MAY 18, 2022
7:00pm EDT
ITEEA's Roundtable Discussion Series
Teaching Energy and Power
FREE TO ALL!
www.iteea.org/roundtable.aspx

June 26-30, 2022
2022 National TSA Conference
Discover Your Journey
Dallas, TX
https://tsaweb.org/events-conferences/calendar/2022/06/26/default-calendar/2022-national-tsa-conference

technology and engineering TEACHER

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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.

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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, Seventh Edition.

Editorial guidelines and review policies are available at www.iteea.org/Publications/Journals/TET.aspx.

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All subscription claims must be made within 60 days of the first day of the month appearing on the cover of the journal. For combined issues, claims will be honored within 60 days from the first day of the last month on the cover.

CHANGE OF ADDRESS
Go to the ITEEA website – www.iteea.org. Log in and edit your profile. It's that simple.

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Send address change to: Technology and Engineering Teacher, Address Change, ITEEA, 1914 Association Drive, Suite 201, Reston, VA 20191-1539. Periodicals postage paid at Herndon, VA and additional mailing offices.

Email: kdelapaz@iteea.org
Website: www.iteea.org

stem education news

Upcoming Deadlines

November 10: Last day to register for the ITEEA REACH Challenge. REACH Challenge is an impactful adaptive and assistive technology design thinking project for middle school, high school, and college STEM programs, showcasing ITEEA's mission that "Technology and Engineering Bring STEM to Life!" Teachers are provided a Toolkit of curriculum and resources to lead their students to create a viable adaptive or assistive technological solution to help someone in their community. Projects can then be submitted to ITEEA for an opportunity to earn awards and funding for their STEM program! Learn more at www.iteea.org/REACH.aspx.

December 1: Deadline to apply for MANY ITEEA Awards and Scholarships. ITEEA's awards program raises awareness of and exposure to the outstanding work being done in technology and engineering education. Award and scholarship opportunities exist for educators at all levels; undergraduate and graduate students; and programs at the elementary, middle, and high school levels. ITEEA award winners will be recognized at ITEEA's 84th Annual Conference on March 9-12, 2022 in Orlando, FL. Learn more at www.iteea.org/AwardsScholarships.aspx

December 1: Last day to register at the Early Bird Rate for ITEEA's 84th Annual Conference, March 9-12, 2022 in Orlando, FL. ITEEA's Annual Conference is the premiere event for professional learning, networking, and sharing best practices with STEM Education colleagues. The 2022 Theme is "Standards for Technological and Engineering Literacy: The Role of Technology and Engineering in STEM Education – Keys to Success!" Learn more at www.iteea.org/iteea2022.aspx.

December 18: Deadline to apply for ITEEA's STEM School of Excellence Recognition Program, which recognizes outstanding schools for their commitment to providing a robust Integrative STEM education program. Schools recognized exemplify outstanding leadership in the field of STEM education. Recognized schools undergo a rigorous application process requiring detailed documentation to demonstrate a strong Integrative STEM program. Learn more at www.iteea.org/STEMschoolofexcellence.aspx.

December 31: Deadline for nominations to the 2022-23 cohort of ITEEA's 21st Century Leadership Academy. This is a program designed to create tomorrow's most successful and respected technology and engineering leaders, consultants, and strategic thinkers. This program incorporates knowledge and experiences from education leaders and other experts using practical and innovative advice on how leaders make a difference. Participants will be involved in important dialogue using the best wisdom from experts and practitioners across sectors. Learn more at www.iteea.org/Twenty-FirstCenturyLeadershipAcademy.aspx.

Engineering systems to explore the edge of space

by Michael Walach

BOREALIS is currently preparing for the 2024 solar eclipse and plans to livestream video of the eclipse from the edge of space.

BOREALIS

BOREALIS (Balloon Outreach, Research, Exploration and Landscape Imaging System) conducts 6-10 flights per year to the edge of space using high-altitude balloons. All the hardware, software, experiments, and payloads are student designed, built, and tested. BOREALIS is a NASA-funded Space Grant project.

Space Grant

The National Space Grant College and Fellowship Project, or "Space Grant" was established in 1989. All 50 states plus the District of Columbia and Puerto Rico have a Space Grant Consortium made up of affiliate sites around each respective territory. The affiliate sites include universities, museums, state and local agencies, science centers, etc. "The 52 consortia fund fellowships and scholarships for students pursuing careers in science, mathematics, engineering and technology, or STEM" (MAY, 2015).

A picture from about 90,000 feet taken on a BOREALIS high-altitude balloon flight. Note the moon top center. Wildfire smoke is the cause of the haze in this image.

Montana Space Grant Consortium is housed at Montana State University in Bozeman, MT and serves about 29 colleges, universities, and other education and industry partners. BOREALIS (Balloon Outreach, Research, Exploration and Landscape Imaging System) is Montana State University's space grant program. BOREALIS conducts high-altitude balloon flights to the "edge of space" with flights typically reaching 100,000 feet and a current record flight in the summer of 2020 that reached 126,000 feet! BOREALIS hires 10-15 interns each summer to work on STEM challenges associated with high-altitude flight. Students design and build all of the systems required for each flight including the ground control stations, ground tracking station, long-range communication systems, in-flight hardware and software, landing prediction software, science payloads, balloon construction for zero pressure balloon flights (balloons that are not sealed at the bottom and do not pop in flight) and many other assorted projects. BOREALIS selects students from any college major and even had one high school student work as part of the 2020 BOREALIS team.

Why Fly High-Altitude Balloons?

Reaching space is hard and expensive. Getting to the edge of space is very difficult and expensive using rockets and most aircraft cannot operate in the thin air and extreme environment of the upper stratosphere. The goal of BOREALIS is to provide students with an aerospace experience that closely meets the mission and goals of NASA. A simple 1-3 kg latex balloon filled with helium can typically reach about 100,000 feet above sea level before it bursts. A zero-pressure balloon made from a thin plastic sheet can reach similar altitudes and, once neutrally buoyant, can float for a long time. At an altitude of 100,000 feet about 99% of the earth's atmosphere is below the balloon. Temperatures can range from -40F to -60F (-40C to -50C). A high-altitude balloon gives students a close analog to actual space flight as similar systems are required: a ground control station that can track the balloon and receive data back while in flight, a system for determining the balloon's position and altitude, science payloads to collect data, and a recovery team to retrieve the "spacecraft" after landing.

What Does a Typical Flight Look Like?

Flight days begin very early with most of the team arriving at the BOREALIS lab around 4:45-5:00am local time. All the gear is loaded into four rental cars/trucks followed by a one- to two-hour drive to the launch site. BOREALIS typically launches from one of three small general aviation airports. BOREALIS has agreements with the airport managers for each airport they launch from and the BOREALIS flight director files a NOTAM (Notice to Airmen) with Salt Lake Center (air traffic control) 24 hours in advance of any flight. The NOTAM contains information such as launch time, projected flight path, and projected landing area as predicted by a balloon flight prediction program (https://predict.habhub.org/). Weather is the biggest factor when planning a flight and planning begins about a week prior to flight. Upper-level winds are one of the biggest concerns. Once the team arrives at the airport, set up of the ground station, payload

Payload string and balloon ready for flight. Several tarps and sheets are placed down first to protect the balloon. Socks filled with sand hold the sheets and tarps down.

boxes, and the balloon begins. Each member of the team has several tasks to complete and soon the launch site is buzzing with activity. Once the ground control station is up and operational, and all the payloads and experiments are confirmed to be powered on and operating, the balloon fill begins. Almost everyone participates in the balloon fill as many gloved hands (to prevent balloon contamination) to keep the balloon from hitting the ground, popping, or becoming twisted are required. Once the pre-calculated volume of helium has been filled into the balloon, the payload string is tied to the balloon. Each payload element is held by team members, and the balloon is carefully launched.

Once launched, the balloon flight is monitored by all team members using a variety of ground tracking systems. It takes about two hours for the balloon to reach max altitude. At max altitude the balloon either pops or the payload is intentionally cut away using a remote-controlled cut-down system, and the payload then floats back down to earth under a parachute. The flight director makes calls to Salt Lake center air traffic control to advise them when the balloon is 30 minutes from launch, when it is launched, and at other key points during assent and descent that are required by air traffic control to keep manned aircraft safely away from the balloon. The balloon's flight path is updated every 10 seconds through the iridium satellite network and uploaded to a webserver that anyone can view including air traffic control. A back up SPOT satellite tracker is included on every flight in the event the main tracking system should fail. Once the balloon has landed, the team departs the airport and attempts to locate the landowner of the balloon's touch down location. Once the landowner is located and permission to cross their property is received, the recovery team drives and hikes out to the balloon's location. Once retrieved, data from the science payloads is downloaded and analyzed.

A still image from a 360-camera taken from the edge of space. The image distortion is a result of the 360-camera.

What is Possible and What Have You Done?

Collecting science and engineering data is not all the BOREALIS does. While picture, video, and sensor data are important to collect, BOREALIS has some less serious payloads. They have flown gummy sharks, a 3D-printed snoopy, and other trinkets to the edge of space. It is rumored that a chicken sandwich was once flown and then eaten upon return from 90,000 feet. In the summer of 2020, BOREALIS broke the Guinness Book of World Records for the highest paper airplane launch with a confirmed altitude of 115,000 feet. At the time of this writing the team has not heard back from Guinness to know if their record will be recognized. While setting records is not typically the goal of their flights, they also broke their personal record with a max altitude of 126,000 feet in July of 2020. BOREALIS is currently preparing for the 2024 solar eclipse and plans to livestream video of the eclipse from the edge of space. BOREALIS is currently developing the software and hardware systems required to stream live video and plans to work with partner space grant consortiums to teach other balloon groups from around the country how to replicate their systems.

I Want to Get Started Flying High-altitude Balloons; What Do I Need?

The minimum equipment required for a flight includes a balloon, a payload (video or still camera, sensors, etc.), a parachute, and a tracking device. BOREALIS has been flying balloons for a long time and has developed many systems that are freely shared with others interested in flying. Getting involved with your local Space Grant Consortium is another great place to look, although not every Space Grant operates balloons. Redundancy in a system is important. Single points of failure should be eliminated whenever possible. A typical BOREALIS balloon will be described below with reductions/changes for the beginner balloonist.

The balloon is usually a 1.5 to 3 kg latex balloon. The weight of the payload and desired altitude will all be used to determine the balloon size and gas required for flight. A burst calculator such as http://habhub.org/calc/ is helpful in planning as are weather prediction websites such as www.windy.com and www.wunderground.com. The balloon, once filled with helium, is then tied to a cut-down system. While a cut-down system is not required, it is better to cut away from the balloon before it pops as the pop is very violent and the balloon can tangle in the parachute and payload string. Beginners getting started in ballooning are better off not using a cut-down system as it adds to the complexity. Instead, beginners can just let the balloon rise until it pops, then float back down under a parachute. The cut-down system used by BOREALIS is a Ni-Chrome wire (same as used in foam cutters) that heats up and cuts the string between the balloon and the parachute, and a back-up system that uses a rotating razor blade to cut the string if the Ni-Chrome system fails. The cut-down system needs to be tied to the main payload string so that it isn't lost after the balloon is cut away.

The parachute is at the top of the payload string after the cut-down string has been cut. Under the parachute is the payload string, which is made up of one or more boxes that contain the flight data instruments, data collectors, cameras, etc. The top payload is always the iridium satellite modem (to assure good communication and GPS signal), which sends GPS data (altitude and position) to the satellite network every 10 seconds. The iridium network sends the data to a server housed at the BOREALIS lab and automatically updated on a webserver http://eclipse.rci.montana.edu. While using an iridium modem provides the best Realtime flight data, the modem costs about $750 and requires a fair amount of computer and network expertise to set up. There is also a service plan required that charges for each byte of data sent and received, plus a monthly fee. Middle or high school technology programs could replace the iridium modem with a SPOT satellite tracker. While the SPOT might not report data at altitudes over 60,000 feet, it will provide the landing location of your payload. It should be noted that for a SPOT tracker to work, it must always point up. BOREALIS 3D prints a "Spot Ball" that keeps the SPOT in the correct orientation. 3D print files for our "SPOT Ball" can be found at the resources link at the end of this article. The ground control station uses GPS data from the iridium modem on the balloon to precisely aim an

A latex pressure balloon about to launch. Pressure balloons have a sealed bottom and pop at max altitude.

A zero-pressure balloon about to launch. A zero-pressure balloon has an opening at the bottom and will not pop. Zero pressure balloons rise until they reach neutral buoyancy then float. They must be flipped upside down to descend.

antenna. The antenna allows the ground team to send and receive commands to and from the balloon.

On most BOREALIS flights there are one or more GoPro cameras for video, a 360-degree camera for video, a digital SLR camera for high-resolution pictures, and a Raspberry Pi camera for high- and low-resolution pictures. Low-resolution pictures are transmitted through a 915 Mhz radio back to the ground tracking station antenna. Updated camera settings can be sent up to the balloon through the 915 Mhz antenna to a Raspberry Pi computer controlling the camera. BOREALIS is also experimenting with long-range video systems to stream live video during flight. The payload boxes that BOREALIS used are made from 0.2" foamboard. A CNC laser cutter is helpful for making the boxes although a sharp x-acto knife and straight edge works well, too. Many parts, such as camera mounts, and payload holders are 3D-printed. Duct tape (referred to as "balloon tape" by the BOREALIS crew) and hot glue are very useful. String or thin rope are used to connect the payload boxes and parachute, and a knowledge of a few basic knots is helpful.

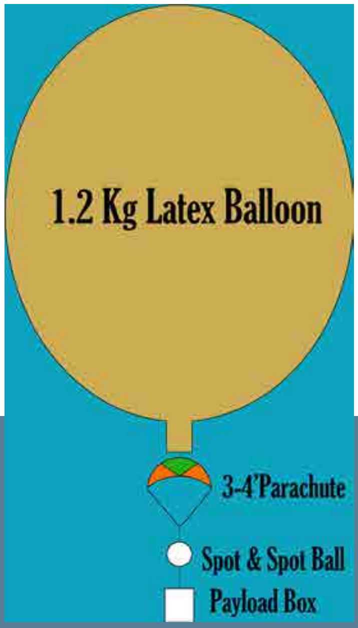

Diagram of what a simple payload string for a beginner balloon might look like.

What Do I Need to Know to Fly Safely?

Knowing the airspace you are launching and landing in is important. It is best not to fly near major airports or population centers. Your local general aviation airport or FAA FSDO (Flight Standards District Office) are good places to ask questions before you fly. There are standards for balloon flight and reading and understanding these rules is critical before you fly www.ecfr.gov/cgi-bin/text-idx-?rgn=div5&node=14:2.0.1.3.15. In general, balloons under 12 lbs. can fly under the exempt category, which has very minimal regulations. Weight is not the only factor, however, as the density of the payload must also be calculated. Generally, the size and dimensions of the BOREALIS payload box with a 12 lbs. or less payload will meet the exempt category. In an abundance of safety, BOREALIS follows all the requirements for heavier payloads regardless of launch weight. Only use helium as a lifting gas; hydrogen can be extremely dangerous as a simple static discharge can cause a violent explosion. Laws differ from country to country and those presented here are only for the United States. Temporary Flight Restrictions (TFRs) can go into effect anywhere and launching a balloon in a TFR can lead to serious legal action. Understanding FAA regulations is extremely important and someone knowledgeable about such things should be a key member of the flight team. A good resource for NOTAMS (Notices to Airmen) and TFRs is www.faa.gov/pilots/safety/notams_tfr/. Respecting private property and gaining landowner permission is very important. Practice leave no trace (www.lnt.org) and leave the land as you found it. Know the hazards in your recovery area and travel prepared. Carry a first-aid kit, plenty of water, sunscreen, and have proper clothing and footwear. Travel in a group and have a means of communication other than cell phones if cell coverage is not reliable in the area. BOREALIS sometimes has to perform recovery in grizzly bear territory so being "bear aware" and carrying approved bear spray is sometimes required. Each launch/recovery environment presents its own unique hazards.

Basic Beginner Balloon

Latex Balloon HAB-600 1-2 lbs (450-907gram) payload	$45	www.kaymont.com/product-page/hab-600
SPOT GPS Tracker	$99	www.findmespot.com/en-us/products-services/spot-gen3
SPOT Service Plan	$11.95/mo + *$19.95 Activation*	www.findmespot.com/en-us/products-services/spot-gen3#service-plans
GoPro Camera *(or similar)*	$229+	gopro.com/en/us/shop/cameras/hero7-black/CHDHX-701-master.html
Parachute 3-4 ft	$50	the-rocketman.com/recovery-html/
Helium	$175	Local Welding Gas supplier. Price varies, but about ¾ of a tank will fill a 1.2 KG balloon.
Payload box *(Foamboard, foam, 3D-printed)*	$10	Local Craft Store
Assorted lines and hardware	$25	Local Hardware Store
Shipping estimate 10%	$65	
Total	$730	

What Can I Expect From My First Flight?

Expect that many things will not work as intended. The air is cold at high altitudes, however, with very little air, many electronic items will overheat despite the cold. The thin air may also cause other systems that function on the ground to fail in flight. Prepare to lose everything that you launch. The chance of a payload being lost is an ever-present danger. Redundancy and experience will limit, but not eliminate, loss of payload. BOREALIS still has a payload in Canada and another stuck in a tree in the mountains of Montana. Things can and will go wrong. Many GPS units will shut off or report bad data above 60,000 feet. It is best to test hardware multiple times before it is used to perform critical flight functions. Despite these challenges, seeing the first picture taken from the edge of space and seeing the curvature of the earth is extremely rewarding. Despite multiple flights, it is still exciting to walk over a hilltop and see a payload safely laying in the grass.

A recovered balloon sitting in a field in the Montana wilderness.

References

May, S. (2015, July 28). About the Space Grant Project. Retrieved from www.nasa.gov/stem/spacegrant/about/index.html

Mike Walach *is assistant professor and program coordinator for the Technology Education Program at Montana State University in Bozeman, MT. He is also the flight director for the Montana Space Grant Consortium's BOREALIS (Balloon Outreach Research Exploration and Landscape Imaging System) program at Montana State University. Mike has been an educator for 21 years teaching engineering and technology at the high school level for 14 years, and at the Collegiate level for 7 years. Mike can often be found flying his paraglider around Bozeman or hiking in the mountains. He can be reached via email at* mwalach75@gmail.com.

This is a refereed article.

STEAM on loan: building "big" in the classroom

by Brad Christensen

The projects investigated in this study are engaging, unusual, and provide a vehicle for STEAM learning in a larger scale than is common with most classroom projects.

The value of doing projects as a vehicle for instruction has been integral to technology and engineering classes for decades. With the increased emphasis on STEM, project-based learning is becoming more popular with all teachers. Realistically, classrooms can be limited, however, in the tools, materials, and processes needed for project-based learning. Life-sized motorcycle, push car, and electric trike kits have been developed and loaned to well over 100 schools and other organizations. These non-consumable projects allow students to build something big that might otherwise be too difficult or too expensive. An online banking simulation was created to teach financial literacy by facilitating the purchase of parts for their projects and the management of funds in their accounts. Research indicates these large projects have been used in a variety of ways to teach a wide range of content with positive results. Most teachers use the projects to teach teamwork and problem solving but others have used them to address specific academic content such as engineering design in *Standards for Technological and Engineering Literacy, Next Generation Science Standards*, as well as measurements in mathematics. They have also been used successfully for whole-school STEM events, professional development for teachers, and team-building experiences for corporations. The kit materials are

The body can be built on the inexpensive mock-up and transferred to the chassis for racing.

inexpensive, and material processing is well within the capabilities of most CTE programs and woodworking hobbyists.

As the number of jobs in the STEM fields has grown over the past several years, the importance of STEM education has become evident. There were 8.6 million STEM jobs in the US in May of 2015 (Bureau of Labor Statistics, 2017). In three years, that number had grown to 9.7 million and it is projected to grow to 10.5 million by 2028 (Bureau of Labor Statistics, 2020). Beyond the employment potential, educators see integrated STEM education as an attractive pedagogical approach. STEM education is a positive contribution to education; "while some teachers see STEM as one more thing they needed to cover in their classrooms, many teachers feel it is a valuable way for students to learn" (Margot & Kettler, 2019, p.12). Margot and Kettler (2019) also documented, however, that most teachers feel inadequately prepared and see many other barriers to their implementation of "hands-on, learn by doing" STEM instruction.

Technology and engineering teachers have utilized the "hands-on, learn by doing" approach since Dr. Calvin Woodward started the Manual Training movement in the 1880s (Woodward, 1969). This pedagogy continues in *Standards for Technological and Engineering Literacy* (International Technology and Engineering Educators Association, 2020). Both the science standards (NSES, 1995) and mathematics standards of the late 1990s promoted the use of projects (NCTM, 2000). *Next Generation Science Standards* and the Common Core State Standards for Mathematics elevate the project further, promoting their use at every grade level through their reoccurring "Science and Engineering Practices" and "Mathematical Practices." (NGSS 2013; CCSSM 2010).

Most projects completed in schools, particularly at the K-8 level, are tabletop models. They often involve snapping together plastic parts from a construction set or are likely made from paper tubes, craft sticks, and bendy straws. Much can be learned from them, but they do not address the tools, materials, and processes of the "real world." Also, there is value in "building big." For example, ergonomics might look fine in a model but not work when a driver must sit in the seat. Often missing, in smaller projects, is the tremendous sense of accomplishment when something life-sized is achieved that was previously considered beyond one's capability. However, a challenge, and negative aspect, is that large projects can be costly.

The projects investigated in this study are engaging, unusual, and provide a vehicle for STEAM learning in a larger scale than is common with most classroom projects. They use tools, materials, and processes that are more realistic to industry and are reusable, so costs are minimal. The projects are made available by a university-based STEM education research center that loans projects free of charge to schools and organizations. Although originally intended for the classroom, these projects have also been used at STEM fairs, community art fairs, corporate team-building events, summer camps, and for teacher professional development to introduce STEAM and how to use a project as a vehicle for instruction. Three projects and a management program are the focus of this article.

Motorcycles

The motorcycle project is a kit that allows the construction of a two-thirds-scale motorcycle. It consists of ten plywood parts that students assemble with nuts and bolts tightened with a 9/16" wrench and socket. The bikes do not roll, but the front fork pivots on a kingpin to simulate steering. Kindergarten students can follow the photos in the printed instructions and assemble a bike with some help in about 90 minutes. Middle schoolers require about 45 minutes and adults can usually do it in less than 30 minutes. Comments and observations indicate that all age groups thoroughly enjoy the experience.

Once assembled, the builders customize their ride using art supplies and recycled materials to build engines, saddle bags, fairings, fenders, exhaust pipes, and other parts. Some students have connected electrical circuits for lights. A few classes have

The motorcycle kits can be assembled by young children with very little help.

The motorcycle is about 5 feet long with a 20-inch seat height.

placed the bikes in front of a fan or leaf blower to analyze airflow. Most, however, simply allow the builders to sit on the bikes, make engine noises, sing *Born to be Wild,* and take lots of photos. When finished, the custom parts are removed and the motorcycles are disassembled and repacked, making them ready for the next group.

Exploration is underway to identify how the motorcycles can be used to teach reading and writing at the third and fourth grade levels. In this program, students read about a fictional class doing the motorcycle activity while they are doing it themselves. This includes reading technical material as they follow the instructions to assemble their bikes. They also write technical material as they design custom parts and create instructions for them. These can be uploaded to a website and available to future builders for their research. Finally, students write a fictional story about an adventure on their bike and illustrate it with digitally edited photos using a green screen.

Push Cars

Push car racing was a popular sport in the early 1900s. Photos of the cars show a variety of construction techniques and materials. Many utilized wooden bodies and steel wheels while others had metal bodies with compound curves and elaborate suspension systems. Races were quite popular. A race in Chicago in the early 1920s involved 200 competitors citywide and an estimated 10,000 people watching the parade, 3,000 of whom followed the cars to the racetrack. (Hall, 1925).

The push car is a four-wheel chassis that is about three feet wide and six feet long. One person drives while two others push. It is made of construction lumber and plywood and includes steering, brakes, and a seat belt. Students build a cardboard body for it and race the cars by pushing them around a racecourse. Since the body is not structural, durability and quality of body construction are irrelevant to safety and performance, making it possible for even pre-school children to be involved. The seat can be replaced with a cushion for larger students and adults.

At most schools, the teacher divides the class into teams that design, build, and race the car. If the teams are large enough, students are assigned other tasks such as team photographer, researcher, web designer, marketer for team promotional materials, and sponsorship logos. In cases where many chassis are needed, low-cost mock-ups have been used, consisting of a wooden frame that is the same size and shape as the chassis but lack the mechanical parts. Students can build their body on the mock-up and then transfer it to a chassis for racing. At the conclusion of the event, the bodies are removed and the cars are delivered to the next school.

Since the cars roll, students can gather time and distance data allowing them to calculate top speed, average speed, and acceleration. They can also measure the mass of the car and driver and calculate force. Timing the speed of the runners allows for proper pairing and heart and respiratory rates can be monitored and compared to resting rates so no runner goes further than their optimum distance.

Photo from "Outdoor Boy Craftsmen" by A. Neely Hall published in 1925. Two chapters address how to build "pushmobiles."

Photo credit: *Hall, A. Neely (Albert Neely), via Wikimedia Commons*

Car bodies can vary greatly in design, construction, and materials.

Photo credit: Mooseheart Child City

Push cars are much faster than expected.
Photo credit: Mooseheart Child City, signed permission form attached

Various lengths of tubing can be used to make many different frame configurations.

One elementary school that reserves the cars each year is located near a racetrack. The teachers organize a special event where several local racing teams work with the 3rd grade students to design, build, and race their cars. This is very popular with the entire community. The cars have been used for a school-wide fitness program consisting of multi-grade teams to encourage physical activity in the middle of winter. Also, a local children's museum conducts an annual push car derby and fundraiser.

Another annual event involves working with an international organization that conducts programing to promote peaceful co-existence. In this program, teenagers from the Middle East visit the United States for a few weeks each summer. They spend several hours working in pairs to build and race cars. Later in the week, they visit a public housing community and lead the push car activity with the children. This event not only addresses STEAM learning but also provides valuable leadership and cultural experience.

Trikes

The trikes project is comprised of full-sized chopper trikes powered by 24-volt transaxles salvaged from mobility scooters. Students form corporations and buy the component parts from the classroom store. They bolt together the frame, front fork, seat, and handlebars. Golf cart or lawn tractor wheels are bolted to the transaxle and several different bicycle wheels are available for the front. The battery pack and motor controller are pre-wired and mounted in a plastic box. Students bolt it to the base frame and connect the motor with a flat-four trailer plug. Given the adjustable base frame and the different lengths available for the wishbone, backbone, down tubes, and front fork, there are over 8000 possible combinations. Some of these combinations will not differ noticeably, while many will not work since either the foot pegs will not clear the ground, or the rake and trail will not be conducive to steering. Students then customize their trike with various art supplies in hopes of raising the selling price of their "really cool" trike. A retail price is calculated and affixed to each trike and then they are placed on display in a common area of the school building. Simulated pre-production orders are accepted from all students. The designers use this data to calculate the costs of parts and labor to determine corporate profit. The trikes are then disassembled, the corporation is liquidated, and the simulated profits distributed to each shareholder according to the articles of incorporation agreed upon at its formation.

The trikes have been shared with a few select schools with promising results. Middle and high school students can assemble a trike in three to four hours if a design and engineering process precedes construction. Engineering by "trial and error" does not work well for a project of this complexity. Getting the triangular geometry correct appears to be the biggest challenge when designing a strong, functional, and aesthetic frame. The trike is not fast, but braking can still be a problem. A braking system is in development that will be effective regardless of the frame configuration and adjustment errors. Pilot-testing has also revealed that teacher training is critical since this project allows design and construction on a level seldom available to middle and high school students.

Banking Simulation

The motorcycles, push cars, trikes, or just about any other project can utilize the online banking simulation to add a financial literacy component. The simulation was originally developed as the management system for the trikes project. It was soon identified as a valuable tool for any project where students are given a budget and must buy their materials from the company store. Each student is given a debit card with an account number and PIN. They access their online account to find the funds the teacher has already placed in their checking account. They present the debit card at the store where it is scanned, and the PIN entered. The clerk then scans the barcode of the item(s) purchased and the amount is automatically deducted from the account.

Students can transfer funds between savings and checking accounts, buy CDs, invest in mutual funds, pay bills, and take out personal loans. All students are preapproved for a credit card, but they must accept the terms before they can use it at the store. The teacher can set up deposits for student salaries.

For group work, students can transfer funds to a corporate account according to agreements they have written for forming, operating, and liquidating the corporation. The Chief Financial Officer (CFO) of the corporation is then given the debit card and PIN of that account and is the only one authorized to use it.

Interest is applied to savings account balances, investments, credit card balances, and loans based on realistic percentages. To make small amounts over short duration reasonable, time is compressed. Teachers set the pace of each quarter, so a three-month period can

The home page of the banking simulation.

be experienced by students in a few minutes, an hour, day, week, or any other duration of choice.

The simulation keeps a running total of each student's credit score throughout the experience. This is based on real-world credit score indicators: debt load, payment history, credit inquiries, credit mix, and length of credit history.

Standards Alignment

The motorcycles, push cars, and trikes provide a rich context for addressing many educational standards in several disciplines. Three standards and multiple benchmarks from *Standards for Technological and Engineering Literacy* (ITEEA 2020) can be taught using these projects:

STEL 1 Nature and Characteristics of Technology and Engineering

- PreK-2 STEL-1C. Demonstrate that creating can be done by anyone.
- G3-5 STEL-1H. Design solutions by safely using tools, materials, and skills
- G6-8 STEL-1M. Apply creative problem-solving to the improvement of existing device or processes or the development of new approaches
- G9-12 STEL-1R. Develop a plan that incorporates knowledge from science, mathematics, and other disciplines to design or improve a technological product or system

STEL 2 Core Concepts of Technology and Engineering

- PreK-2 STEL-2E. Collaborate effectively as a member of a team.
- G3-5 STEL-2I. Describe properties of different materials
- G6-8 STEL-2S. Defend decisions related to a design problem
- G9-12 STEL-2W. Select resources that involve tradeoffs between competing values, such as availability, cost, desirability, and waste, while solving problems.

STEL 7 Design in Technology and Engineering Education

- PreK-2 STEL-7A. Apply design concepts, principles and processes through play and exploration
- G3-5 STEL-7I. Apply the technology and engineering design process.
- G6-8 STEL-7U. Evaluate the strengths and weaknesses of different design solutions.
- G9-12 STEL-7X. Document trade-offs in the technology and engineering design process to produce the optimal design.

Next Generation Science Standards, Common Core Mathematics and Common Core English/Language Arts, Physical Education, Social Studies, and Art standards were reviewed. Well over 100 standards were identified that could be addressed in the context of these projects. A document listing the standards by discipline and grade level including specific instructions for addressing each was made available to the teachers when they reserved the kits. To simplify implementation, an instruction sheet was created with guidelines for addressing several overarching educational objectives, project management ideas, and safety considerations.

Logistics

Using an online form, most teachers request the motorcycle, car, or trike kits for one to three weeks, depending on how they intend to use them. Through communication with the teachers, the delivery schedule was adjusted to efficiently visit several schools on a single trip. Most deliveries involved the use of a small trailer. Four cars can be stacked for storage and transport, so 16 will fit in a 12-foot trailer. Eight motorcycle kits will stack into a 42-inch cube allowing 16 kits to fit in a large van. Parts for five trikes will fit in the box of a standard pickup truck.

Dimensioned drawings for building the motorcycles and push cars are available free of charge by contacting the author. The trikes are still in development, so photos and sketches can be shared but no finalized plans or curriculum materials are currently available. Inquiries, ideas, and offers for collaboration are welcome.

Production of the motorcycle kit, car chassis, and trike is well within the scope of technology/engineering or career/technical education programs. They are excellent manufacturing projects allowing high school students to be involved in the creation of educational materials that could be loaned to teachers throughout the district. Materials to build one motorcycle kit cost about $100 and a push car chassis can be built for $185. Push car mock-ups cost $15 each. Trikes are considerably more expensive due to the electrical components. The prototypes cost about $350 each. Sponsorship of the program could be attractive to local businesses or industries, particularly those with a connection to motorcycles or cars.

The banking simulation can be set up for just about any project where items are sold to the students. A custom storefront can be created containing the inventory and prices determined by the teacher. Bar codes and debit cards can be printed from within the system.

Evaluation Information and Data:

Fun projects are always popular, but not necessarily educational. Most of the teachers reported that "the kids loved them." To identify how the projects are utilized for education, a teacher survey instrument was implemented addressing the following research questions:

1. How much time is spent with the projects and how many students are involved?
2. Which teachers (disciplines and/or grade levels) are using them?
3. Why are the teachers using them?
4. What are students learning from this experience?
5. What are the responses from students, parents, other teachers, and administrators?
6. Does the use of these projects have any impact on teaching?

The three projects were reserved 79 times by 48 different schools or organizations for use between July 1, 2019 and June 30, 2020. All schools across the state were closed starting March 16 due to the COVID-19 pandemic so about a quarter of these reservations were cancelled. Teachers were asked by email to complete the survey within two weeks of using the project, which was administered online via Qualtrics. Twenty-one teachers completed the survey, representing a 78% response rate.

The post-use survey indicated that the time with the project ranged from one hour to 20 hours with the mean being about 6.7 hours. They were used with between eight and 400 students at each school with a mean of 70. Science teachers made up 28% of the respondents while another 19% stated they taught science and other subjects, including STEM/STEAM. Those teaching only STEM/STEAM made up 14% of the respondents and 29% stated they taught math, special education, technology, and/or social studies. The remaining 10% conducted special instructional programs and teacher professional development.

Nearly two-thirds of the teachers (62%) reported they used the projects for team-building and problem-solving. Others mentioned teaching aerodynamics (10%), Newton's Laws (5%), acceleration and motion (5%), encouraging trade careers (10%), engineering design (48%), and reading directions (29%). About half of the teachers (48%) addressed specific academic standards, primarily for engineering design and forces and motion. In all cases, the teachers' expectations were met or exceeded. "Students went above and beyond with designing and building parts for the choppers," reported one teacher. Another stated, "We have used the choppers a number of times and I am constantly amazed at the leadership and creativity that grows from the interaction with the choppers."

When asked what the students learned, responses covered many skills including:

- "Teamwork, design, how to follow directions to put the chopper together, work ethic"
- "How to use specific tools, how to wire a circuit to create lights that really worked for headlights"
- "Mechanical engineering, physics"
- "The application of potential energy in a system as it transfers to kinetic energy"

One teacher reported on their process:

> *"The seventh and eighth grades did the projects in a small group setting with no support from the teachers except to follow the directions and work together. The seventh and eighth graders then became facilitators of the elementary students. They could not do it for the younger students."*

Responses from students, parents, other teachers, and administrators were equally positive. A few of the responses include:

- "They loved this project! Principal actually took part in the racing and videotaped the students and put it on our school's Facebook page."
- "One parent expressed that is was very enjoyable! He and his child felt a part of the class while last year the boy spent a lot of time excluded in the hall at his previous school."
- "Parents said it was a good idea to have students do other activities that did not require computer use. The principal was very supportive along with other staff members who stated it was good that students are incorporating other skills such as art. Students were very appreciative to use their artistic skills in science where they got the opportunity to design a t-shirt for the driver and different components of the car body."

The use of the projects has provided students and teachers some exposure to nontraditional pedagogy. When two motorcycle kits were delivered to a classroom for second grade students with behavior disabilities, the children unpacked the kits and got started while the teacher was working out how to organize the activity. Upon seeing their initial progress, she sat down and watched them read the instructions and successfully complete the project without intervention. Nearly one third of the teachers (29%) stressed the importance of taking a "hands-off approach" and allowing the students to figure out the problems, teach each other, and take initiative in the design process. One comment was, "Just let the kids have fun, then guide them through everything they learned!" Another comment involved guest speakers, "I invited a staff member's son and his friends to come in and show their choppers to the class. They spoke about exhaust, sissy bars, oil pans, etc. and this class asked GREAT questions!"

One administrator expressed some concern about storage and safety of the push cars. A few crashes with the cars have been reported but no roll-overs and no significant injuries have occurred. Two teachers mentioned that the instructions should be more precise with "lots of pictures and video" while another felt the directions were too specific.

Conclusion

Loaning STEAM projects to schools is a great way to help teachers overcome barriers to a quality STEAM experience. Students gain experience with realistic tools, materials, and processes through a fun and engaging project. Teachers appreciate that they can do something unique and exciting in their classrooms at little or no expense. Students are thrilled, thinking these projects are "just about the coolest thing (they) have ever done in school." The projects are particularly effective at getting parents involved since it is fun for them also.

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teaching artificial intelligence

in technology and engineering education

by Euisuk Sung and Juhyun Kim

Using the model trained through Teachable Machine, students and teachers can understand the principles of artificial intelligences by practicing the process of collecting, training, and running the machine learning technology.

Introduction

With the wide use of advanced computing technology in our daily lives, there are growing calls to teach artificial intelligence and automation in technology education. The new *Standards for Technological and Engineering Literacy* (*STEL*; International Technology and Engineering Educators Association, 2020) introduced eight contexts in which the first context is computation, automation, artificial intelligence, and robotics. For many years, the trend in technology and engineering education has moved toward computer-oriented technologies such as robotics, programming, and computer-aided design (CAD). The concepts of automation and artificial intelligence were introduced more than six decades ago and became pervasive in our daily lives through actively using them in various products and services including product design, banking systems, self-driving cars, voice recognition, and language translations. For example, when watching a YouTube video, the online system automatically generates a list of suggestions for the next playlist. Some architects use generative design to produce an optimal design solution that meets specific constraints and criteria. Despite the importance of automation and artificial intelligence, little is known about how to teach these complex concepts to K-12 students. This article will introduce the concepts of artificial intelligence and exemplar lesson ideas that integrate them with technology and engineering education contents.

What is Artificial Intelligence?

The concept of artificial intelligence was first introduced in Greek mythology (Mayor, 2019). Talos was a giant bronze robot designed to defend the kingdom of Minos of Crete. Its mythic description illustrates an automated robot programmed to fight enemies with advanced intelligence. Afterward, in 1950, Alan Turing (1912-1954), one of the pioneers of modern computer science, published a milestone paper in which he proposed the conceptual framework of the artificial intelligence that thinks like human beings (Li, Zheng & Wang, 2018). The term artificial intelligence was introduced in 1956 by John McCarthy (1927-2011), an American computer scientist and cognitive scientist (Bach, 2020). He coined the term and designed various computing tools including ALGOL, time-sharing, garbage collection system, and machine learning. Later he mentioned that machines as simple as thermostats can have beliefs, and having beliefs seems to be a characteristic of most machines capable of problem-solving performance themselves. In recent years, the use of artificial intelligence exploded with the accumulation of usable data sets on the internet and the development of computing algorithms.

Often the term artificial intelligence is used for an automated machine, but it has a broad meaning that describes the ability of a machine that simulates intelligent human thought processes including computer vision, natural language processing, and pattern recognition (Wang, 2019). One of the fundamental principles of artificial intelligence is that a machine learns new things automatically. It means that if we program a machine to have a mechanism to learn rules and parameters itself, it could think like a human who learns new things. For K-12 students, the concept of artificial intelligence can be considered too hard to understand, but this article will introduce how machine learning can be brought into the technology and engineering classroom using a simple tool kit, Teachable Machine.

What is Teachable Machine?

Teachable Machine is free online software developed by Google designed to introduce the concept of machine learning without complex computer programming. This article will demonstrate how technology and engineering educators start machine learning using Teachable Machine with three steps: 1) gathering data, 2) building a model, and 3) testing the model. In order to start Teachable Machine, visit its official website powered by Google at https://teachablemachine.withgoogle.com/. Teachable Machine provides three types of machine learning projects: image, audio, and pose.

a. Image project: collect images from a camera or files

b. Audio project: collect audio data from a microphone or files

c. Pose project: collect poses of animated images from a camera or files

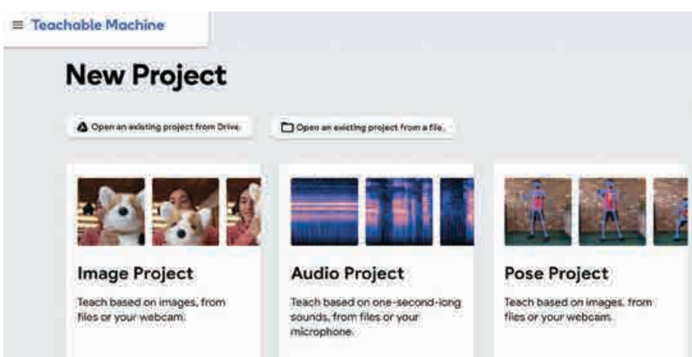

Figure 1.
Teachable Machine project page

Each project requires a series of training processes including data collection, learning, and previewing. Once we train the machine using our custom data set, we can test and export the model as a programmable file such as JavaScript or Python. The downloaded source file can be used to control a physical machine used in the technology and engineering classroom. As the principle of machine learning relies on mathematical models built on provided data by users, known as training data, the accuracy of predictions or decisions relies on the input data. Teachable Machine provides its own machine learning algorithms and user interface, so that we can simply compile our custom data sets to build our own machine learning model.

Making a Ripe Tomato Collector

This example shows how to make an automated ripe tomato collector using machine learning. On the main menu page shown in Figure 1, we need to select Image Project. The first step to build a model in machine learning is classification. The classification refers to a group of predictive features that make the model unique from others. For example, in this article, the authors will train a machine that automatically detects ripe or unripe tomatoes shown in Figure 2.

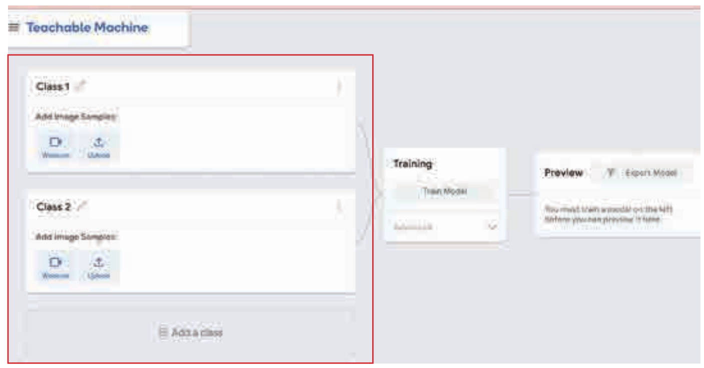

Figure 2.
Teachable Machine training page

The training page consists of three steps: 1) classification, 2) training, and 3) testing and exporting. In the first step, we need to change the name of each class. In this example, we will create two classes, Ripe and Unripe, so we need to set the class names. In order to train the machine, we need to provide image data by uploading files or capturing images from a web camera. For this sample project, the authors prepared two sets of tomatoes images: ripe and unripe. We can upload images by clicking the Upload button on each class and select ripe and unripe tomato images as shown in Figure 3. Since machine learning works based on a statistical probability, more images yield a more reliable model. Once you provide images to the machine, then click the Training Model button to train your machine. Training a model may take from a few seconds to several minutes depending on the complexity and amount of data. When model training is completed, the working model can be previewed as shown in Figure 4. When shown a green tomato on the camera, the model will indicate a certain range of probability as to whether it is ripe or unripe such as 90%, 95%, or 99% and will change when we move the tomato. This is because a change of camera angle could produce a different image that affects the probability of the model. In machine learning, the probability only tells a level of confidence for the object based on the data we provided. This example used tomato pictures to train a model, but we can use other types of images like mask or no-mask, left-hand or right-hand, and cats or dogs.

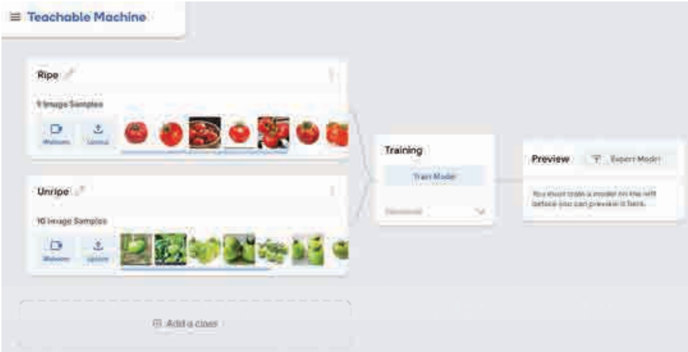

Figure 3.
Training Machine using tomato images

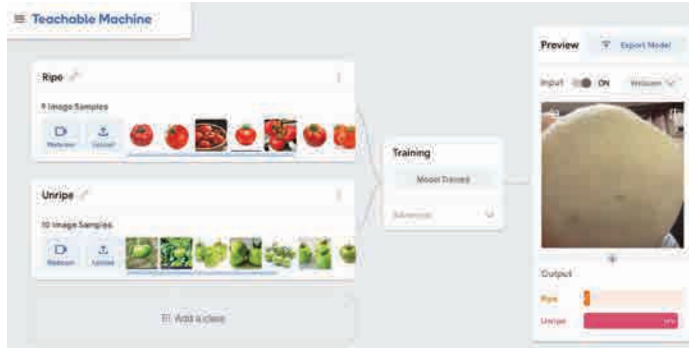

Figure 4.
Testing the model for tomato collector

Integrating Machine Learning into Technology and Engineering Classroom

One of the advanced features of Teachable Machine is that it allows users to export the trained model to expand into physical making. Teachable Machine provides three options for exporting the model: Tensorflow.js for web-based projects, Tensorflow for Python projects, and Tensorflow Light for mobile programming shown in Figure 5. In this project, we will use Tensorflow for Python, which can run in the PC settings. We can click the Export Model button and select TensorFlow on the export page. Then, download an encapsulated file that contains a model file (keras_model.h5) and labels.txt that are generated by Teachable Machine.

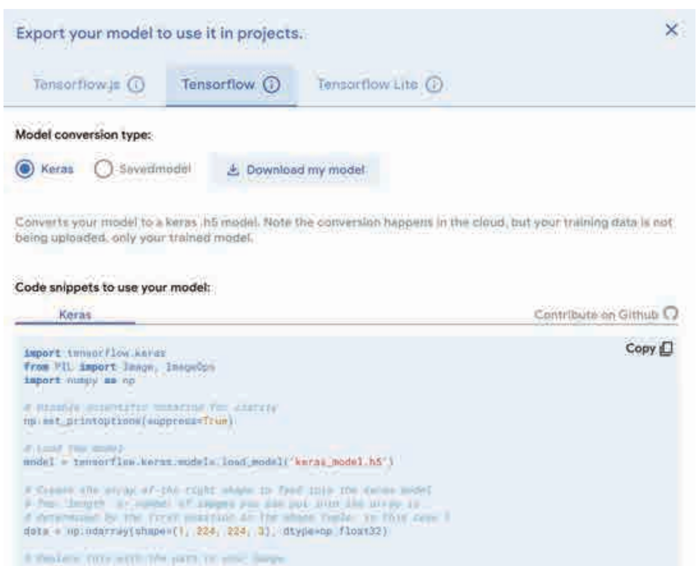

Figure 5.
Model export options

Teachable Machine provides source codes to run your model as shown in Figure 5. To run the model on our computer, we need to create a Python file named test.py using a text editor and copy and paste the source codes into the file. The sample source codes load our model and execute it with an image file designated "test_photo.jpg." Therefore, we need to locate an image file named "test_photo.jpg." To run the Python codes on our computer, you will need to install the Python compiler (see www.python.org/downloads/) and utility modules including tensorflow, keras, pillow, numpy. These modules can be installed using commands shown in Figure 6. For the compatibility with these modules, we recommend installing Python 3.6 or 3.7 and tensorflow version 1.15.

```
$ pip install tensorflow == 1.15
$ pip install keras
$ pip install pillow
$ pip install numpy
```

Figure 6.
Install Python Modules

Then we can execute the python sample codes on a command prompt by typing python test.py (see and execute the source codes saved in test.py shown in Figure 7).

```
$ python test.py
```

Figure 7.
Run Python codes on your local computer

Figure 8 shows the result of the model run through the Python codes.

Closing: Discussion and Suggestions

The demonstration of machine learning introduced in this article can be used in all K-12 education settings. Young students in Grades 3-5 can start learning the concept of machine learning as *STEL* noted in TEC-1. At the middle school level, Grades 6-8 can start planning and implementing their own machine learning, and if possible, start integrating it with physical making. High school students, Grade 9-12, can use this tool not only to further explore careers, but also to apply to their robotics project. Using the model trained through Teachable Machine, students and teachers can understand the principles of artificial intelligences by practicing the process of collecting, training, and running the machine learning

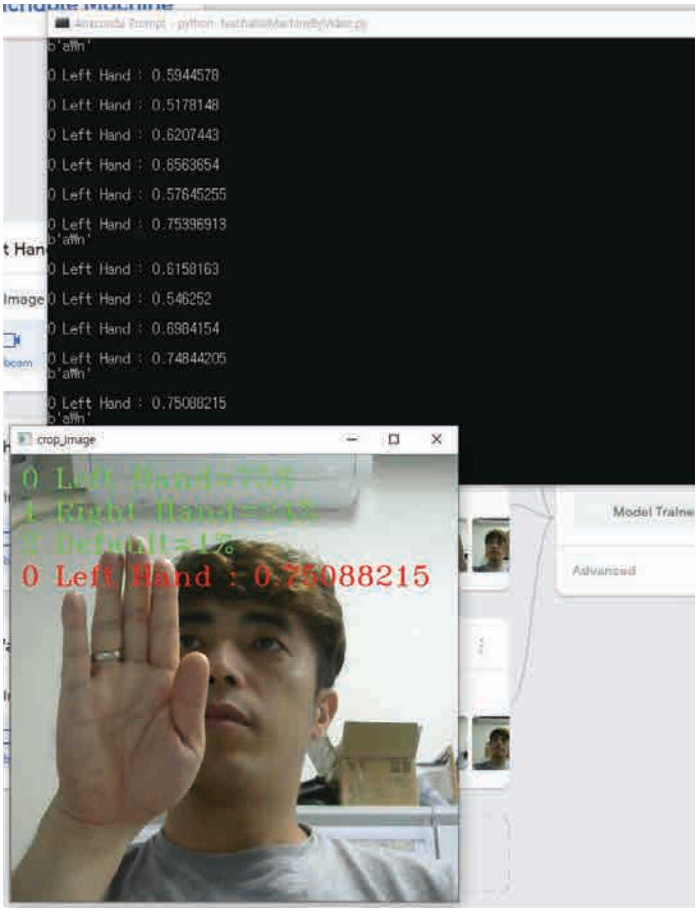

Figure 8.
Figure 8 Running Model on PC

technology. Figure 9 shows an application of the artificial intelligence into a technology classroom activity where students built a prosthetic arm that always loses in the rock paper scissors game (see https://github.com/mtinet/teachableMachineProject). Additional lesson ideas can be obtained through the above GitHub project site and Teachable Machine Tutorial at [https://teachablemachine.withgoogle.com/.](https://teachablemachine.withgoogle.com/)

STEL notes that the primary goal of K-12 technology and engineering education is to foster technological and engineering literacy, which is the ability to understand, use, develop, and evaluate technological products, services, and designs. Aligning to *STEL*, for example, this activity can be applied to **TEC-1:** Computation, Automation, Artificial Intelligence, and Robotics, **STEL-3J:** Connect technological progress to the advancement of other areas of knowledge, and vice versa, and **TEP-4:** Critical Thinking. In a lesson, students can develop an understanding of technological and engineering application with the integration of technological problem solving with machine learning.

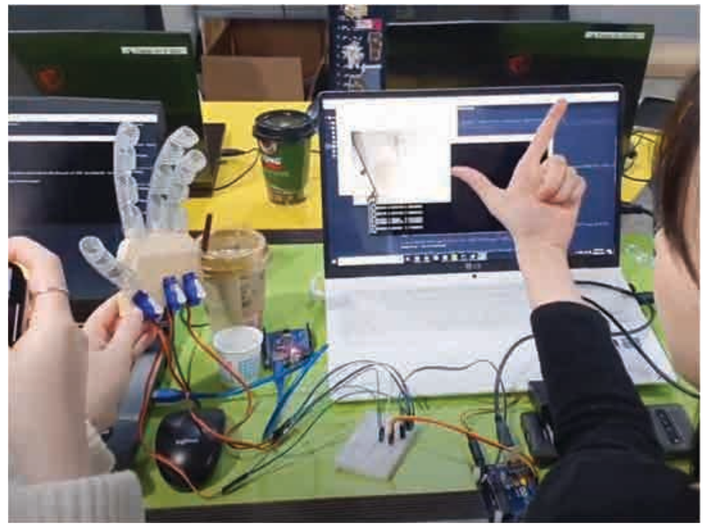

Figure 9.
Application of artificial intelligence into physical making

Also, teachers can highlight critical thinking by practicing the machine learning activity where students can learn how computers are capable of comparing and evaluating evidence and making decisions based on computational modeling with input data (see Table 1).

The use of artificial intelligence will help young students broaden their understandings of the pervasive machine learning technology, but is not limited to its basic uses. As shown the example in Figure 9, the hands-on approach used in K-12 technology and engineering education acts as a disciplinary integrator where students used various techniques, skills, and knowledge across the school subjects such as math, science, technology, and arts. In technology and engineering education, computational thinking is not a theoretical term, rather it ties to real-world problems where students design, make, and program physical devices through the habits of mind in engineering and computational thinking (ITEEA, 2020; Sung, 2019). This approach makes technology and engineering education unique in that it helps young students become "doers" with the ability to learn and use computational thinking to solve complex real-world problems.

Table 1.
An example of *STEL* alignment for Grades 9-12

Standard	Practice	Context
Standard 3: Integration of Knowledge, Technologies, and Practices	**TEP-4:** Critical Thinking	TEC-1: Computation, Automation, Artificial Intelligence, and Robotics

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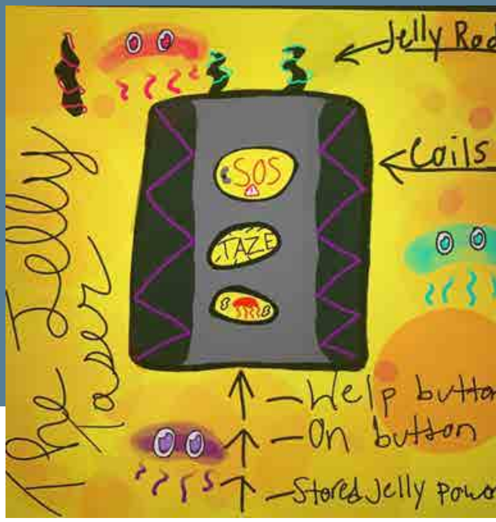
This is a refereed article.

project-based learning in an online environment

by Dylan DelPiano

When people think about Technology and Engineering Education it is almost synonymous with the word "project." To those of us who teach the subject, it means Project-Based Learning. The Buck Institute for Education defines Project-Based Learning as, "a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge." (What is PBL, 2020). The idea behind this teaching technique is to help students build their creativity and problem-solving skills on a large project that challenges them to create something that may or may not solve a problem. Though not a dramatically new idea, it is a staple for any Technology and Engineering curriculum. When schools suddenly went to online learning in March 2020 it left T&E teachers with the difficult task of attempting to apply the staple of PBL in an online environment. Here, the author will recount some of the ways that he and co-workers supported PBL during their year-long switch to virtual learning. The intent is to provide some ideas and starting points for fellow teachers interested in keeping Project-Based Learning as a main course in our curriculums regardless of the delivery type.

Prior to delving into some of the online implementations of PBL, it is critical to understand the demographics of and resources available to the author, and more importantly, the students in an urban middle school in Pennsylvania. The school has two Technology Education certified teachers for Grades 8 and 9 and a STEM teacher for Grade 7. The author teaches the 8th grade sections where the first focus is on the proper use of wood-

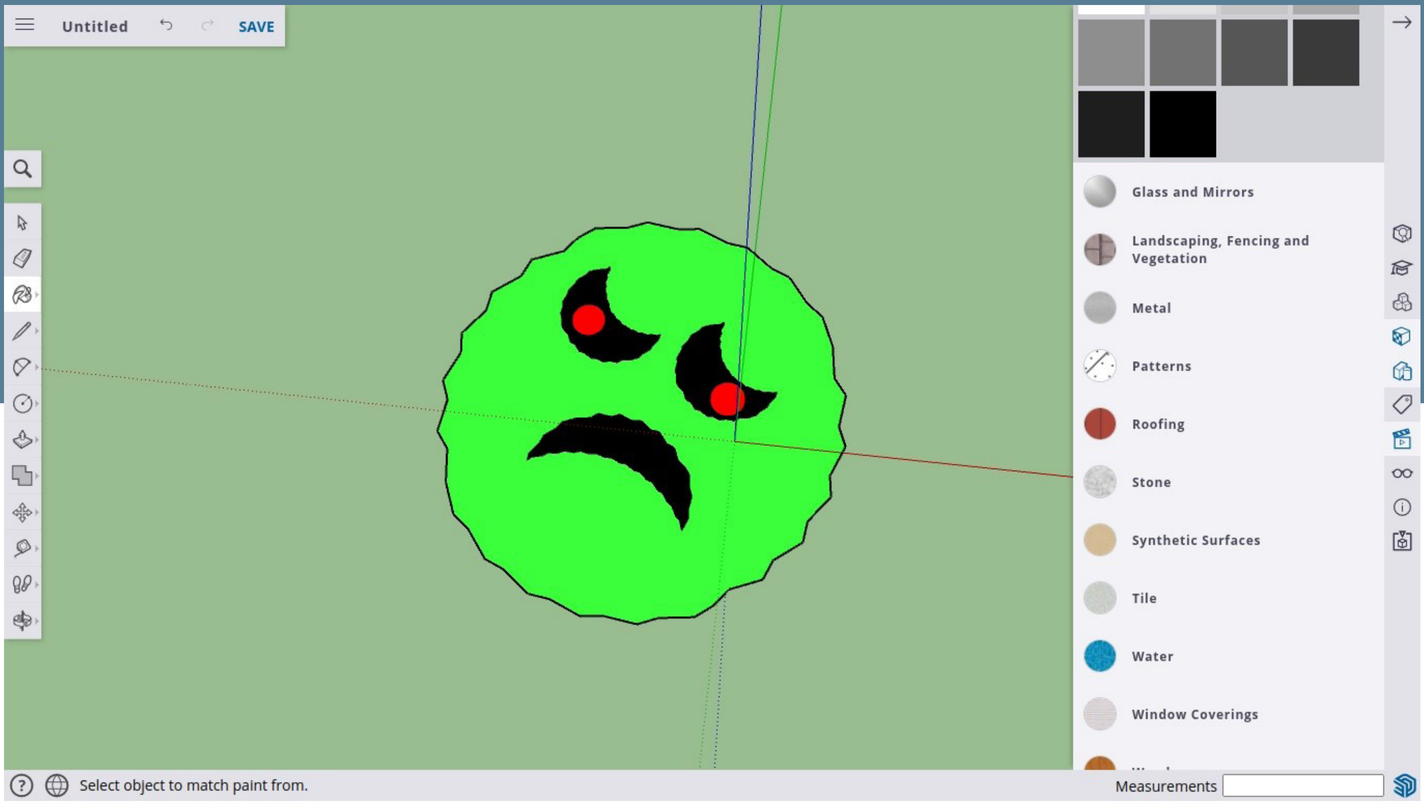


working machines and then extends to design challenges using wood and various other materials. As a low-income school, no lab fees are required, and all supplies and tools are provided via pinching our budget's pennies and dumpster-diving for cardboard. Though perhaps a slight exaggeration, it underscores that the students are truly grateful for the handcrafted products they produce in our classes and that switching to virtual delivery would preclude continuing these projects. However, all was not lost as the school had gone one-to-one with Chromebooks the previous year, allowing each student to connect to their teachers online. During this time the author and his colleagues put their heads together to attempt to continue that same sense of creation even if students were cut off from the resources and supplies found in the technology labs.

Many of the design challenges done with students center around the application of the Technological Design Process. The first project was formed around a popular trend at the beginning of the lockdown. Everyone was home and Rube Goldberg machine videos were appearing on YouTube like wildfire. So, why not capitalize on this trend and have students try one of their own? Rube Goldberg's claim to fame was "accomplishing by complex means what seemingly could be done simply." (Merriam-Webster) Typically one initial trigger sets off a series of chain reactions leading to the completion of a simple outcome. Our project's task was to use the Technological Design Process to plan, design, and develop a Rube Goldberg machine and then record it in action. The first obstacle was how to track progress and provide feedback during this process. In school, it's easy to view students' progress through interaction and observation as they participate. Google Classroom was not only the central place for all assignments and resources but also a place where teachers could give immediate feedback. Built into the program are comment sections, individual to each assignment, where students could post progress pictures, pose questions, and receive teacher suggestions on the direction of their project. This feature mixed in with mandatory project checkpoints and allowed the students to get the guidance they needed as they worked at home. One of the most valuable aspects of Project-Based Learning is having the students working together toward a common goal. This helps develop cooperation skills that students can use when in the workforce. Having students at home prevented working together on a physical project. To support this cooperation element in the curriculum, certain days were called Collaboration Days where the students would do just that, collaborate! Using Zoom's breakout room feature the students were separated into small groups where they discussed the project with their classmates. Initially, students prepared answers to open-ended questions about how their project was progressing. This allowed the students' conversations to start naturally and flow as they discussed their projects. As the project continued, the prepared questions were relaxed as they became more comfortable talking virtually. Though by no means ideal, this added some sort of collaborative element to the project that helped the students who actively participated.

The greatest obstacle for the classes to overcome when designing PBL for virtual learning was the feasibility of projects. When designing projects there are multiple variables to consider that made planning a nightmare. Such variables include differences in student resources at home, being able to distribute material for students to take home, students who stay at different houses throughout the week, functioning technology, space within houses to work, etc. The Rube Goldberg project was a great intro lesson for the teachers because it highlighted a lot of these problems. Flexibility with these issues was the key and the project's design itself allowed a great tolerance. The project's supplies themselves are things typically found around the house, allowing students to use what they have on hand. The size of the project is also something that has many options. It could be the size of a foot cube or stretch across multiple rooms in a house depending on the constraints in each household. Project selection and the feasibility of any given project is key when thinking about online learning. It must be flexible and able to bend to many different constraints or it may create barriers for some students.

Our Rube Goldberg project took about a quarter of the school year to complete with the students coming every other day. It was a project that really got the teachers and students' feet wet when thinking about the idea of how to incorporate hands-on aspects that we usually do in tech ed class into a virtual environment. Though there were a lot of ups and downs, it was a project that shifted the students from the computer screen and on to something in the physical world. Throughout the rest of the curriculum, which moved on to other projects, the teachers took many of the ideas gathered from the Rube Goldberg project forward. Future projects allowed expanding students' choices when developing final solutions to design challenges. After short one-off lessons on SketchUp, students were given the option to use this program to design 3D models. With the option to make a physical model with recycled materials, students would be able to design in the way that was most feasible and enjoyable to them. Below are additional links with brief descriptions of resources found to



be useful when trying to apply Project-Based Learning to a virtual technology education curriculum. As we start to head back inside school, we will no doubt be getting back into the swing of the Tech Ed class we all know and love, but with the unpredictable nature of the world around us you never know if you need a virtual assignment on deck just in case!

Helpful Resources

1. **SketchUp For Schools:** www.sketchup.com/products/sketch-up-for-schools
   A great site for kids to learn any kind of 2D or 3D modeling, with many options for projects such as mechanical design, product design and even architecture. The program is web-based so there is no downloading program files on the computer itself. SketchUp also connects with Google Drive, allowing students to save work in the cloud. The best thing about SketchUp for Schools is that it is pre-packaged with the Google Suite so there is no need to purchase additional programs.

2. **Beanz Magazine:** www.kidscodecs.com/sections/all-stories/sketchup/
   a great collection of activities for SketchUp with students practicing various tools and techniques on the program. There are a variety of intro and more advanced activities with students learning through specific designs made in the program. The step-by-step instructions are intuitive and include multiple images as well. This site on Beanz Magazine is a fantastic introduction to SketchUp, which can then be used for design challenges of your own.

3. **Tinkercad:** www.tinkercad.com/
   Another web-based computer drafting program. This free software is a great starting place for students who will then move on to Autodesk because it is made by the same company. The real value of Tinkercad is its electronic circuit-creating tool. Students can manipulate a circuit in a virtual environment and have them light up and play sound just like a physical version would. For any type of electronics unit, this feature is worth checking out.

4. **Google Classroom:** https://classroom.google.com/
   A one-stop shop for most, if not all, of your virtual classroom needs. Create assignments, add materials, grade student work, email students, and so much more. The benefit for Project-Based Learning is that it allows easy communication with kids on individual assignments through the program's comment sections, allowing for direct feedback on any given project. Another great aspect of Google Classroom is that it connects to many other programs, creating a seamless ecosystem of technology.

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let's collaborate!

Fly Norfolk: Aviation Institute of Maintenance's STEM summer camp in aerospace

by Joel A. English and Ben Clark

Academic programming in science and technology shapes the young mind in ways that can allow a young adult to gain confidence, skills, and the intellect required to convert academic experience into a meaningful and rewarding career. However, we know that the social pressure and extracurricular activity of high school distracts most students from taking an authentic interest in STEM programming in ways that lead to a career after high school. By the time students reach high school, they're usually *too cool for school,* and it can be too late for them to latch on firmly to science and technology subjects deeply enough to plan a career in those subjects or orient their post-secondary education toward STEM after graduation.

We know that the key is to get to students early. STEM-related youth programming in elementary and middle school can plant seeds inside the hearts and minds of students, so that when they wake up in the last years or months of high school and begin to think about "what's next," they have already been introduced to STEM careers and understand what is possible for them.

An example of STEM experiential learning has been alive in Norfolk, VA for the past several years at the Aviation Institute of Maintenance (AIM). AIM is the largest educator of FAA-certified aircraft mechanics in the world. AIM graduates take the Federal Aviation Administration exams necessary to obtain their mechanic's certificate with ratings in both Airframe and Powerplant. AIM operates campuses in Atlanta, Charlotte, Chicago, New York, Philadelphia, Dallas, Houston, India-

napolis, Las Vegas, Washington, DC, Kansas City, San Francisco Bay, Orlando, and its flagship campus in Norfolk, VA. AIM is responsible for over 23% of all certified aircraft technicians in America each year.

This summer, AIM offered its 5th Annual *Fly Norfolk* Jet Camp at its Norfolk campus on East Little Creek Rd. Sixteen middle school students from Norfolk Public Schools' Azalea Garden Middle and Norview Middle were engaged in hands-on STEM activities to provide exposure to a plethora of aviation careers, including Aviation Maintenance Technician, Certified Drone Pilot, Airline Ground Operations, Commercial Piloting, and yes, Rocket Scientist. Through multiple projects, students learned about the four principles of flight, space exploration, drones, careers in the aviation industry, how weather impacts aviation, and more.

Through independent activities and team-building projects, students walked away from *Fly Norfolk* with a newfound sense of confidence, social skills, and work ethic. The camp's curriculum was designed so that activities grip students' attention. As one camper's mother said, "My child went to *Fly Norfolk* feeling excited each day and came home more excited to return the next day. It wasn't your typical summer school. My child was inspired."

On the first day of *Fly Norfolk,* AIM faculty engaged students in a friendly paper airplane contest. Students judged each other's final paper plane projects within categories of distance, speed, aerial tricks, flight-time, and best overall design. During activity, AIM faculty taught the principles of flight: weight, thrust, drag, and lift. This simple yet educational activity allowed students to feel comfortable in their new environment, make new friends, and challenged them to think from an engineering standpoint.

Other activities included learning to fly drones, negotiating an obstacle course in AIM's gym, and fabricating metal clipboards and picture frames, which gave students a lot of hands-on time with a drill press, electric sander, rivet-gun, and other metal-bending machinery. AIM took pictures of each student building their frame and placed that photograph into the student's final picture frame project. These projects provided tangible memories of the students' growth while at camp.

Other activities included designing, engineering, and launching water bottle rockets and space lunar rovers with NASA, practicing drone flights, and troubleshooting engine repair. Additionally, students sat in airplane cockpits, received a glimpse of piloting via our flight simulator, and participated in different engine start-ups during camp. The goal was to keep the young minds stimulated every day without allowing the students to get bored. Keeping the students moving, both physically and mentally, was a key component to camp success.

Fly Norfolk hands-on activities were supported by guest speakers who spoke to campers regarding careers in the aerospace industry. Guest speakers from NASA, FedEx, Southwest Airlines, NASA, Signature Flight Support, WAVY TV-10, and iFly Media shared with the students the benefits of working within aviation and how to start a career from a young age. Guest speakers also reminded students of their individual potential, strengths, and how to ask for assistance when facing life issues.

AIM firmly believes that role models matter. To this end, *Fly Norfolk* ensured that guest speakers represented all walks of life, so that each camper could easily relate to at least one adult. Teaching younger generations about careers in aviation is important; however, making a child realize that they are intelligent and can offer a great deal to the world is even more crucial. The Mayor of Norfolk, Dr. Kenny Alexander, said it best, "AIM is giving young people the opportunity to understand their value to society through a vocation. We want our young people to put down the gun and pick up a tool. We want to give them values and hope where they might not otherwise have hope. That's what will make our culture stronger, and our families escape patterns of poverty."

Ashley Oden, Campus Executive Director of AIM Norfolk, said, "It has been so much fun watching these young people explore aviation. They've had the opportunity to fly drones, work with NASA, tear apart aircraft engines, build rockets, and so much more. It's our hope that they've learned a thing or two, but more importantly, that they leave with a ton of great memories. It's always been important to AIM to invest our time, energy, and resources into the next generation, and these kids made it so worth it. They are incredible and undoubtedly will do great things." Ben Clark, Associate Director of Academic Affairs plans to expand the program into additional offerings, stating that "We hope to grow this camp again next summer, and we're looking into a Christmas and Spring Break camp." Those interested in enrolling their children for future camps can contact Mr. Clark at [bclark@aviationmaintenance.edu.](mailto:bclark@aviationmaintenance.edu)

Joel English, Ph.D., *is Executive Vice President at Centura College, Aviation Institute of Maintenance, and Tidewater Tech, where he leads 20 campuses across the country. Dr. English was Chairman of the Board for both the Accrediting Commission of Career Schools and Colleges (ACCSC) and the Career School Private Education Network (CSPEN), and he formerly served as CEO of Ohio, Illinois, Colorado, and Miami Media Schools (2013-2015). From 1999-2014, he was an Assistant Professor of English and Distance Learning at Old Dominion University after finishing a Ph.D. in Rhetoric and Composition at Ball State University. He has written extensively on distance learning technologies, including* Plugged In: Succeeding as an Online Learner*, published by Wadsworth Learning/Cengage in 2014.*

Ben Clark *is Associate Director of Academic Affairs at Centura College, Aviation Institute of Maintenance, and Tidewater Tech. Mr. Clark was a former campus director at Centura College's campuses in Chesapeake and Virginia Beach, he oversaw international business development at AIM for several years, and he currently supervises all student services and career services over the 20 institutions. In August 2021, Mr. Clark was recognized nationally by* Aviation Maintenance Technology Magazine *as a winner of the 40 under 40 award for his work with youth aviation programming within the* Fly Norfolk *program. Mr. Clark holds an MBA from the University of Louisville and is currently pursuing a Ph.D. at Hampton University.*

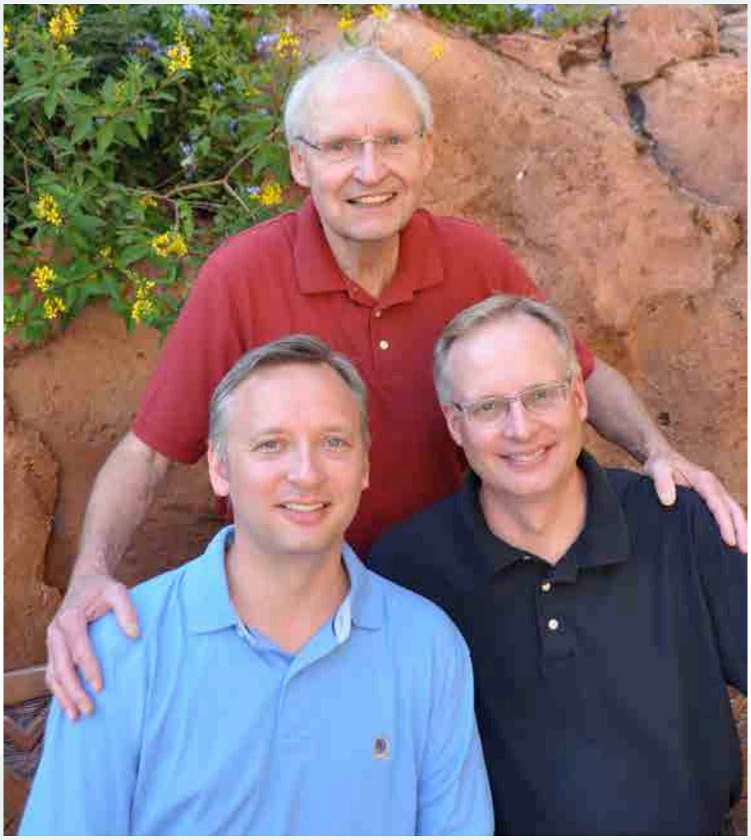
the legacy project

Leonard F. Sterry

Many vocational education, technology education, and now technology and engineering education leaders have made their mark on our profession. Their legacy is something that members of the profession enjoy and have a responsibility to continue and build upon.

This is the eighteenth in a series of articles entitled "The Legacy Project." The Legacy Project focuses on the lives and actions of leaders who have forged our profession into what it is today. Members of the profession owe a debt of gratitude to these leaders. One simple way to demonstrate that gratitude is to recognize these leaders and some of their accomplishments. The focus in this issue will be on Dr. Leonard Sterry.

by Leonard F. Sterry and Johnny J. Moye, DTE



Teacher, Supervisor, and Teacher Educator

Dr. Leonard F. Sterry

Place of birth: Chicago, IL

Married to: Sharon for 55 years

Degrees Held: B.S. Industrial Education, M.S. Vocational/Technical Education, Ph.D. Educational Administration

Occupational History:
High School Teacher, Area Coordinator, State Supervisor, University Teacher Educator, ITEA Curriculum Associate, Educational Consulting

Describe the outstanding programs in the State of Wisconsin when you were a supervisor and teacher educator. What did industrial arts/technology education curriculum and instruction look like during the era of the 1970s and 80s?

Prior to this era, industrial arts consisted primarily of coursework in traditional areas such as craft woodworking, metalworking, drafting, and the like. There was little discussion of curriculum and more about exchanging project ideas. But then things began to change. For one, the field began to feel the impact of the innovations of the 1960s and early 70s. While there were many across the country, we had two significant initiatives in Wisconsin, namely the American Industry Project at the University of Wisconsin-Stout and Industriology at the University of Wisconsin-Platteville. These projects were aimed largely at addressing our long-standing objective of helping students to understand industry and its role in society.

Although the innovations of the 60s and 70s seemed perfectly reasonable when measured against our objective of "understanding industry," they were met with some resistance across the country by many teachers, supervisors, and teacher educators. But the projects had an impact, and not everyone resisted the potential change. Although many projects did not survive as originally intended, they had an impact on some school programs and, possibly more importantly, they established a base for continued local, state, and national curriculum work in our field. In Wisconsin we didn't have a state-level industrial arts curriculum guide for decades. So, during the early 70s we developed a state guide with a committee consisting of teachers, supervisors, and teacher educators representing our traditions as well as American Industry and Industriology.

During the 70s-80s era industrial arts provided students with hands-on lab experiences that were applied in a variety of ways. Some students simply enjoyed the lab work, while others developed entry-level marketable skills. In Wisconsin there wasn't much of a differentiation between industrial arts and trade and industrial education. Back then technology was less sophisticated, so it was possible for students to be employed in some entry-level occupations directly out of high school. But even then, they were encouraged to get at least some post-secondary education. We had a close relationship between secondary and postsecondary education.

However, we were beginning to feel the impact of the Vocational Education Act (VEA) of 1963 in a positive way. Wisconsin elected to implement the legislation by developing programs in the comprehensive high school setting. This was accomplished by using existing labs, expanding some, and in a few cases building new ones. Funding could now be used to upgrade equipment and provide professional development. To qualify for funding, teachers needed to have some related work experience. But these were all B.S. degreed and already certified teachers. So for a portion of a day they would teach general education applications and part of the day toward career-oriented objectives. Because Industrial Arts and T&I were more similar than different, the Industrial Education concept evolved. Importantly, middle school programs were also strengthened during this time, even though they were not funded by the 1963 legislation. Industrial arts funding came later when it was included in the '68 and '72 amendments to the 1963 Act, as I recall. Several of us were invited to provide input to writing the rules and regulations for these amendments.

As technology evolved, discussions started about broadening our content parameters to include a broad range of technologies without abandoning our past. This occurred during the mid-1970s. And although the content wasn't clearly defined, we established a "sandbox" in which to work as new national curriculum initiatives began to evolve in an effort to conceptually define what later became Technology Education. I'll discuss some of these initiatives a little later in this article. However, in the meantime, we moved forward in Wisconsin by making changes for consistency, consistent in that K-12 programs were retitled as technology education, teachers were state certified as technology education, prospective teachers earned B.S. degrees in technology education, and the state association became the Wisconsin Technology Education Association (WTEA). While these changes were positive and helpful, there was, and still is, a lot of work to be done. But we had a focus. We worked together—K-12 schools and agencies, post-secondary technical, universities, industry, and others.

You were an outstanding teacher, supervisor, and teacher educator during your career in a state that had many innovative programs. How did you and your colleagues make that happen and then have the ability to sustain those programs?

Prior to the mid-1960s, Wisconsin didn't have a state supervisor for any phase of industrial education. As a result, and to their credit, state universities provided leadership largely by way of the teachers they produced. But as already discussed, there was only slow technological innovation and very little call for curricular change during this era. And the state association only held a two-hour meeting in conjunction with the state teachers' association annual conference.

In about 1965, the Wisconsin Department of Public Instruction (DPI) hired a supervisor for T&I education. In 1968 I had the privilege of becoming the first state supervisor for industrial arts at the DPI. The T&I position was funded from the VEA of '63 while the industrial arts position was funded, in part, from the National Defense Education Act (NDEA) after industrial arts was added to that legislation. We shared an office, and that helped to build a relationship between general and career-oriented education that resulted in industrial education and later technology education.

Universities continued to make modest adjustments in the preparation of teachers. But to their credit, they were enormously helpful in building a vibrant and sustainable state association, the Wisconsin Industrial Education Association (WIEA) that later became the Wisconsin Technology Education Association (WTEA). The organization moved from a two-hour-a-year event to a two-day conference, with a variety of programs and vendors helping to support the efforts. Later, regional weekend conferences evolved that combined professional development with some quality family time. An excellent newsletter was also published, with a lot of folks pitching in to help. That initiative continues today. And in keeping with our spirit of togetherness, the association board consisted, and still does, of a balance and wide range of secondary and post-secondary representation.

So in answer to the question, the Wisconsin Department of Public Instruction played a role in coordinating a variety of initiatives, including a focus for technology education as it has evolved from industrial arts to technology and engineering education and potentially on to an ever-expanded role in education, blending the objectives of general and career-oriented education, assisting with certification and preparation of teachers, participating with vibrant state and national associations, and communicating with educators, policy makers, and the general public. But balancing these emphases can sometimes be challenging. It helps to have a big-picture, long-term and comprehensive view of global conditions and student needs while managing shortsighted quick-fix responses to single issues. With a long-term vision in mind, various initiatives that come along can be considered and, when appropriate, applied to the longer-term vision.

What were the best techniques for getting teachers to try new ideas?

Change is difficult for many. It requires that we move out of our comfort zones and take on some calculated risks. So, it's difficult to get teachers to consider new ideas. Teachers who are willing to consider change are probably, to a large degree, self-motivated. They tend to be creative, open-minded, hardworking, and realize that their students will be living long, productive lives with rapidly changing technology while participating in a challenging work and life environment.

With that being the case, the leadership challenge was one of providing information and building a rational basis for why a particular change was worthy of consideration. But then it was also important to have training, materials, and, whenever possible, some financial support available. Having said this, trying new ideas is largely a matter of attitude. So those who objectively considered new ideas and change are the ones who deserve credit for improvements in our field and, as a result, benefits to their students. In fact, these were often the teachers who considered new ideas and initiated change. And they were believable because change wasn't just an abstract idea. They were doing it every day with students and, as a result, provided examples for others to consider. As a continued and longer-term investment in program improvement, teacher education introduced new thinking in undergraduate and graduate education. And state and national associations provided a venue for discussion.

How has state and local supervision for the profession changed since the time that you were the Wisconsin Industrial Arts State Supervisor (1970s) until the end of that century (Year 2000)?

Looking way back to when I started as state supervisor for industrial arts, national supervision was mostly committed to supporting traditional content, with little interest in objectively considering the innovations of the time. That's going back to the late 1960s and early 70s. But that changed as some attitudes evolved toward rethinking the content of our field, and new supervisors began serving in that position. Some states had a supervisor, while others did not. In fact, some states actually had more than one supervisor during that era, VA and NY as I recall. But that was highly unusual.

I was actively involved with the American Industrial Arts Association (AIAA) Council for Supervisors until I left supervision and joined the faculty at the University of Wisconsin-Stout in 1978 and became more heavily involved with teacher education. So, after that time I can speak primarily on supervision in Wisconsin and am able to say with confidence that we have had outstanding supervisors since then. And I'm proud to say that several were my advisees while they were university students. Although it's a little outside the timeframe you asked me to address, I did want to mention that I later worked with some excellent supervisors as part of the Center to Advance the Teaching of Technology & Science (CATTS) and other initiatives when I joined the ITEA (now ITEEA) staff as a senior curriculum associate. And what an honor it was to work with these supervisors, leadership persons across the country, the professionals at the ITEA offices, and others committed to technology education and the evolving addition of engineering.

But looking back over the years, I think supervision is still faced with challenges that are similar to those of the past. It's still important to have a comprehensive plan for direction but with flexibility to accommodate new ideas without having narrow, short-term, expedient initiatives derail the plan.

You worked on a significant curriculum initiative, the Curriculum Implementation Project, also known as the Chicago 10 Project, in the 1980s, designed to take the historic Jackson's Mill Curriculum content to a different level of implementation. Briefly tell us about that project and what it was designed to do.

The Jackson's Mill Industrial Arts Curriculum Theory did an outstanding job of framing content for our field, placing it in a broader context of human adaptive systems, and establishing a basis for what later became Technology Education. But although it made an enormous contribution to our field, it was a theory and not a curriculum guide. So there was a gap between theory and practice. That resulted in the Curriculum Implementation Project (CIP), sometimes known as the Chicago 10 because ten of us worked on the project at the Technical Foundation of America offices in the Chicago area.

So using the Jackson's Mill Curriculum Theory as a framework and drawing upon the innovative projects of the 60s and 70s along with the lab-based history of our field, the Project identified four technological systems. These included manufacturing, construction, communication, and transportation systems. And importantly, these were systems, not clusters! More will be said about this. The Project analyzed these systems, organized the content as a series of courses, established appropriate grade levels, and suggested coursework that could be offered in small, medium-sized, and large school districts.

Going back for a moment to systems rather than clusters. For purposes of the Project, systems are an analysis of human adaptive technological activity or depiction of a field for purposes of study. They grow outwardly by adding detail that can be organized as courses for study. Clusters, on the other hand, are headings under which traditional content can be placed. For example, manufacturing is a system and not just a heading for conventional metal machining, welding, and the like. I'm taking time to mention this because of the Project's intent and the attempt by some to use the work for clustering. Admittedly, clustering may have an application elsewhere, but that was not the intent of the Curriculum Implementation Project. While on the topic, our more recent Standards were sometimes used as a checklist against which traditional content was measured rather than as a framework for curriculum development as intended. Having said this, I could cite examples where very traditional programs were checked-off against the Standards with a conclusion that the Standards were already being addressed.

But back to the discussion at hand about the Project and an application example. Wisconsin, with permission, published the Curriculum Implementation Project curriculum document as its state curriculum guide. It might be worthy of brief mention that there was another national curriculum initiative, *A Conceptual Framework for Technology Education,* that followed the Curriculum Implementation Project and preceded the development of our *Standards for Technological Literacy.* But that Framework is another conversation. However, in Wisconsin we were also developing state standards for technology education, parallel to the development of the national standards. This enabled us to provide input to the national initiative while developing corresponding state standards.

In your opinion, did the profession take the right turns or directions with what has evolved as curriculum in the present day? Why?

Yes, for the most part, but there continues to be a gap between theory and practice. I'm using theory in a very practical sense. It's important to keep us moving forward. But while we see some excellent examples in practice, there still seems to be a strong gravitational pull back to more conventional programs. And there are reasons for why this is the case, some understandable while others not so much.

I've already mentioned what I'll call theoretical initiatives like the innovations of the 1960s and 70s, the national curriculum projects that followed, and our standards to mention a few. So, we've had good direction. These efforts have helped us to expand the scope of our field to include new, emerging, evolving, and enabling technologies while positioning us for technologies of the future. And the engineering initiative provides a valuable context in which to practice. But within these contexts, we've probably missed some opportunities. Yes, there are positive examples, but we haven't really capitalized on opportunities to the extent possible with, for example, energy and power, information and communication, production and service, business and enterprise, invention and innovation, and the like. But there's nothing new about this observation. Our curriculum guides and standards have already identified with these areas of content. So, it's largely a case of minimal implementation and not so much about direction.

Admittedly, technology is advancing rapidly, and I'd venture to say that we haven't seen anything yet. So keeping up in our programs is challenging. It's time-consuming, to a degree costly, and just plain hard work. Having been a high school teacher, I get it. Collectively as a profession, we haven't always provided teachers with the necessary materials, professional development, and resources needed to address these content areas. But in fairness, new ideas haven't always been willingly accepted.

Lately I've been involved with National Science Foundation-Advanced Technological Education (NSF-ATE) projects and centers at the postsecondary level but still get into high schools with some projects. I'm mentioning this because of ATE's attitude about looking forward and taking some calculated risks toward rapid technological change and workforce development. It's exciting, positive, and futuristic getting ahead of the curve. We might want to consider connecting with some of those projects.

So, in summary, thank you for the opportunity to reminisce a bit. It's been fun to look back and reflect. I guess that's what old-timers do. But my orientation is still to the future. It's relatively easy and somewhat comforting to remember the initiatives that went well but a bit painful to identify with efforts where we could have done better. So, using the questions asked of me for this article, I've tried to provide an historical overview of our field as I recall it over the past half-century. Together, I expect we have made a positive difference for our students, communities, and country. So maybe we can learn from our past, build upon it, and continue our efforts well into the future. Thanks again!

Thank you Dr. Sterry for taking the time to recall and tell us about your part in these significant events in our profession. Your observation about reflecting on the past but focusing on the future should be direction the readers of your Legacy should follow.

The Legacy Project has now interviewed 18 very influential leaders. It is beneficial for current (and future) leaders to read about the issues that existed and how they were addressed "back in the day." In a few months the next interview will appear in this journal. If you have a suggestion of a leader to recognize, contact the author with that person's name and contact information.

Leonard F. Sterry, Ph.D., *started his educational career as an industrial education teacher and then became a Regional Vocational Education Coordinator. He went on to be the Wisconsin State Supervisor of Industrial and Technology Education as well as taught new technology education teachers at UW-Stout. He also served as ITEA (ITEEA) Senior Curriculum Associate and NSF-ATE Project evaluator.*

Johnny J. Moye, DTE *is retired from his position as a Supervisor of Career and Technical Education at Chesapeake Public Schools, Chesapeake, VA. He can be reached at johnnyjmoye@gmail.com.*

teacher highlight

Tanya Blackwell (Riggins)

Technology Education Teacher

Frederick Douglass High School

Upper Marlboro, MD

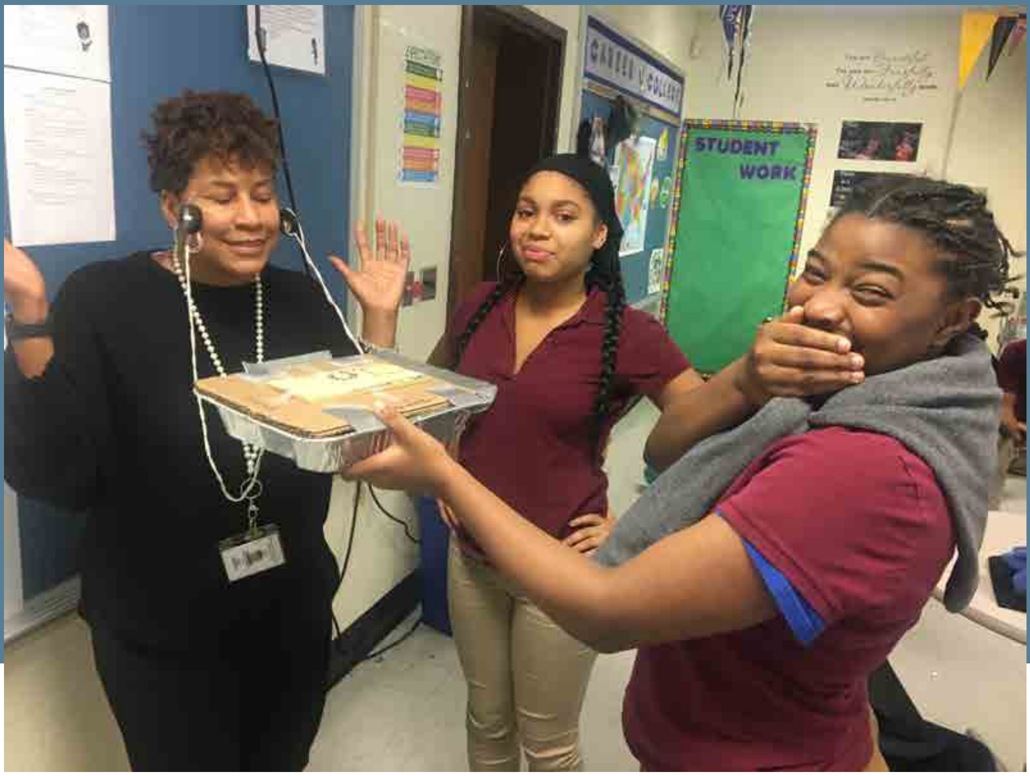
Tanya Blackwell (Riggins) teaches Foundations of Technology *and* Foundations of Computer Science *and is the* Advanced Technological Applications *Lead Teacher. She has been teaching* Technology, Engineering, and Computer Science *since becoming a teacher. Tanya retired from the military after 20 years of service, entered a career in Information Technology, and then decided to become a teacher.*

What inspired you to become a technology and engineering educator?

Since the second grade I knew I wanted to join the Army; I never dreamt I'd do anything else in life. In high school, college was not on my radar at all, just graduation and joining the Army. At my first duty station in Camp Humphreys, Korea, my friends and I decided to sign up for college classes. My first job in the military was communications and computers and it was an easy choice to align my undergraduate studies with that field. Throughout my enlisted years in the military I enjoyed many different options this career field had. I loved the many opportunities and directions that technology and engineering could take me, so I stuck with that field when I became a teacher. I love the creativity of the field and the fact that technology and engineering are found in almost every job and career field available.

What do you consider your greatest successes in the classroom?

Many students don't originally share the same love for engineering and technology that I do, but most enjoy the hands-on activities that I include in the curriculum. When the students become engaged and curious about a topic and they start to make connections, ask questions, try things on their own, and especially when they come back to tell me they showed their parents or siblings something that we did in class, to me that is the greatest success.



Can you share an example of a classroom failure from which you learned?

I feel that if I learned from it then it's not a failure but I do recall a time I taught my class the wrong way to calculate Ohm's Law and then had to reteach them the correct way. Being transparent about the different times that I have failed helps to bring a comfort level to my students. I think it lets them see that I am not perfect and that I don't expect perfection from them.

What is the best thing about being a T&E teacher?

The best thing about being a T&E Teacher is that the field changes and grows so much that each year I learn something new to teach my students and I am always excited about it. Being a T&E teacher allows me to introduce real-world challenges to my students. These challenges and ideas are going to be the topics that they will face and confront as they go forward in their education and careers.

What would you say to students today who are considering careers as T&E educators?

Technology and Engineering touches every career field that you may be interested in, so it is in your best interest to, at the very least, have a foundation in Technology and Engineering. I would also tell them to network and to continue to work on their collaboration and soft skills and that they will solve problems as a team, and they all bring a different and important perspective to the table. I would encourage them to continue to work on their problem-solving and critical-thinking skills as those skills will help then no matter which career field they pursue.

What are you planning to explore and pursue in your classroom in the near future?

In the near future, I would like for my students to explore a real-world problem with students in another country. I feel that clean water (along with cyber warfare) is our next global problem, so I would like to work on engineering solutions for that in my classroom. I want to teach my students to be risk takers in everything that they do and to learn to be better collaborators.

classroom challenge

the entrepreneur course challenge

by Harry T. Roman

Introduction

How would you do it—design a course that teaches students about the increasingly important topic of entrepreneurship? It is a very desirable skill for the workplace, and a powerful stimulant to the economy. Real job creation is coming out of small- to medium-sized businesses, places where entrepreneurs can exist at many levels within a company, which means understanding the business as well as the technical aspects of new innovations is absolutely crucial. Your students see entrepreneurship all the time on TV... it's called *Shark Tank,* and there's a reason it's so powerful and exciting. It brings ideas directly to the marketplace. New companies can get formed and people can become employed. This is capitalism in action.

Understanding Entrepreneurship

Let's start by asking lots of questions, understanding exactly what entrepreneurs do all the time. First, what is an entrepreneur? According to Wikipedia:

> *Entrepreneurship is the process of designing, launching, and running a new business which is often initially a small business. The people who create these businesses are called entrepreneurs. Entrepreneurship has been described as the "capacity and willingness to develop, organize, and manage a business venture along with any of its risks in order to make a profit." Entrepreneurs act as managers and oversee the launch and growth of an enterprise. Entrepreneurship is the process by which either an individual or a team identifies a business opportunity and acquires and deploys the necessary resources required to make it work.*

There is a great deal of responsibility in the hands of an entrepreneur. Perhaps it would be best to have students first study past and present entrepreneurs to see how they changed the world. How about a wide range of people like Henry Ford, Elon Musk, Thomas Edison, Steve Jobs, Harvey Firestone, Dean Kamen, John D. Rockefeller, Andrew Carnegie, Bill Gates, Ted Turner, Jeff Bezos, Mark Zuckerberg, Carlos Slim, Mary Kay Ash, Sergey Brin, and others? Where and what were the opportunities they saw and how did they make something significant happen? Are there any commonalities in their quests to create new products, new jobs, and real advances in the wealth of this country?

Are there experts you can invite into the classroom to help students learn firsthand how entrepreneurs are agents of change—perhaps folks who have started new businesses in your town or in neighboring areas?

Can students identify the kinds of risks and challenges entrepreneurs must learn to overcome to bring their ideas to market? How do entrepreneurs deal with failure and setbacks? Can students develop a list of characteristics that entrepreneurs possess? Are they both leaders and managers?

What kind of education do entrepreneurs need to be equipped to live in a globally competitive world? Is there a college course/courses that one could take? Is college necessary? Of America's great entrepreneurs, how many did go to college? Should all types of college attendees take a course in entrepreneurship? Why or why not?

What areas within the economy might be especially ripe for an influx of entrepreneurial thinking, and why?

Make it Happen in the Classroom!

Make entrepreneurship happen in the class with some great activities, like, but not limited to:

- Assemble student teams to develop new products and services they decide are necessary (after reviewing various fields and business activities).
- Identify the areas and topics they must be able to understand and deal with to make their "dreams" come true. How will they obtain the information and insight needed?
- Maintain a log or notebook of progress toward their goals. Give updates regularly of their progress. Make plenty of sketches and graphics of their concepts, progress, ideas, and even suggested advertising needed.
- How can teams integrate other parts of their academic studies into their entrepreneurial plans….like the socio-economic-environmental-political aspects of the marketplace/world?
- Do pitch contests where student teams compete for resources to fund their ideas.

Can your student teams capture their experiences in a kind of guidebook that you can mold into a series of lesson plans or a course on entrepreneurship?

Should other aspects of your school/district be invited to be a part of this learning experience, such as:

- Business teachers
- Technology education teachers
- STEM teachers
- Others?

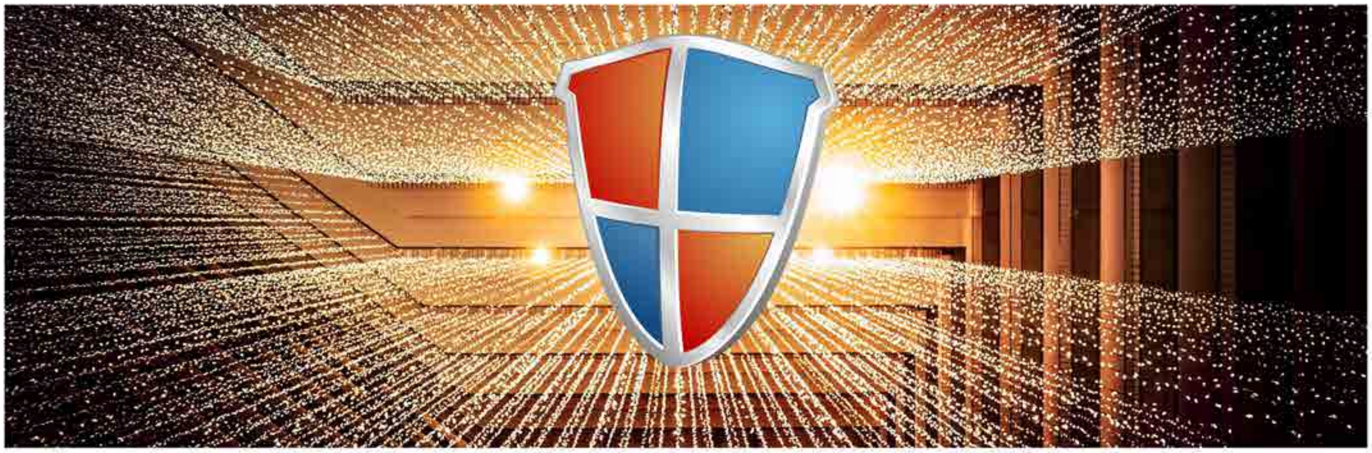
How about involving members of the business community, town council, mayor's office, and others?

Maybe your parent-teachers association might like to be involved?

This is a dynamic and worthwhile activity for students, showing direct relevance of school to the world of work. Students will respond powerfully and with great enthusiasm. Every time I have been involved with pitch contests, students were overflowing with ideas and motivation. They want to make a difference in the world—show them how!

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

ITEEA STEL CTL™
Micro-badging Professional Learning Series
2021-2022



Micro-badging is a hot topic in education! These bite-sized visual representations provide clear evidence that learners have acquired a specific skill and are sought after by employers. Micro-badges are portable, easy to consume, and easy to trust.

ITEEA's STEM Center for Teaching and Learning™ is offering two monthly micro-badging 10-hour professional learning series focusing on safety in the STEM classroom and digital learning. Participants may register for any number of sessions, from one to ten.

September sessions now available!

2021-2022 Safety Micro-badging Series

- **General Safety Topics in STEM Education (Sept):**
- Safer Lab Design and Maintenance:
- Chemical Safety:
- 3-D Printing Safety:
- The Work Permit System;
- Safety in the Robotics Lab:
- Handheld and Portable Tools:
- Large Power Tools:
- Safer Makerspaces
- Accident Reports!

2022-2022 Digital Literacy Micro-badging Series

- **Effective Online Teaching (Sept)**
- Technology Use vs. Integration
- Ethics with Computer Science and Coding:
- Best Practices When Delivering Online Content
- The Flipped Classroom
- Blended Learning Tools for Teachers and Students:
- Video Integration
- Augmented Reality and Virtual Reality
- Creative Assessment and Literacy Tools to Enhance Learning
- Computing Technology Innovation

For more information, including session descriptions, dates, and pricing, please visit:
www.iteea.org/microbadge.aspx

ITEEA AWARDS AND SCHOLARSHIPS

Highlighting Technology and Engineering Educators!



Recognize the Efforts of Outstanding Colleagues! ITEEA Makes it Easy!

We all have colleagues who routinely go the extra mile on behalf of their coworkers and students. Isn't it time that their contributions and achievement are celebrated? YOU can make that recognition happen by nominating someone for an ITEEA Award.

ITEEA created its awards program to raise awareness of and exposure to the outstanding work being done in technology and engineering education. Award and scholarship opportunities exist for educators at all levels: undergraduate and graduate students and programs at the elementary, middle, and high school levels. ITEEA award winners will be recognized at ITEEA's 84nd Annual Conference on March 9-12, 2022. Apply or nominate before December 1, 2021.

- Applaud excellence in the classroom through ITEEA's Program Excellence and Teacher Excellence Awards.
- Apply for an ITEEA Foundation Scholarship to support your educational goals.
- Recognize service through the Distinguished Technology and Engineering Professional (DTE) and Emerging Leader (EL) distinctions.
- Nominate the outstanding work of colleagues through one of ITEEA's Special Recognition Awards.
- Highlight collaborative efforts through the William E. Dugger Exemplary Collaboration Award.
- And many other opportunities!

Full award and scholarship details are available at www.iteea.org/AwardsScholarships.aspx

Don't wait - apply by the December 1 deadline!

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