# HANDS ON!

A magazine for mathematics
and science educators

TERC

SPRING 2020

3
Innovate to Mitigate

# CONTENTS



# Letter from the President

In this issue of *Hands On!* we give you a glimpse into the ways TERC engages learners to ensure fruitful learning experiences including establishing a common understanding, building on the learner's passion, and experiencing hands-on research.

By creating a modern-day version of traditional science fairs, Drs. Puttick and Drayton harnessed student's interest in and concern for climate science in *Innovate to Mitigate*. In two pilot challenges, youth ages 13–18 engaged with peers and scientists, while participating in a global effort to reduce emissions via an online platform. Learn how the project leveraged social media in the development of this youth-led, action-focused learning community and of the science knowledge gained by the students.

In *What is CT?*, Teon Edwards and Mike Cassidy surveyed teachers utilizing a variety of tools, to capture their definition of computational thinking (CT). A topic of much debate at present in education, CT lacks a commonly-shared definition or roadmap as to how it should be applied in K–12 classrooms.

*TERC Scholars Program* interns, Boston University students Katie Yao and Nicole Shearer reflect on their work with TERC researchers. Katie shares how her experience raised her awareness of needed changes in academic and workplace settings to aid in underrepresented groups' success. Nicole's passion for youth advocacy was strengthened by supporting paraeducators' learning community.

Dr. Blanton shares how she and her colleagues came to conceive of *Learning through an Early Algebra Progression* (LEAP). You will get a peek into this supplemental program, backed by a decade of research and piloted in schools across the country. LEAP for grades 3–5 will be available June 2020 from our publisher, Didax.

Enjoy the issue.

Laurie

Laurie Brennan, *President*

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*Hands On!* is published semi-annually by TERC, a non-profit education research and development organization dedicated to building futures for all learners through STEM education and teaching.

# Innovate to Mitigate

## Combatting Climate Change One Project Idea at a Time

By Brian Drayton and Gilly Puttick

The ecosystem of formal STEM education has always included activities such as science competitions and science fairs. Their special purpose is to provide students with opportunities to experience and practice science as it is practiced and experienced in the real world.

In the *Innovate to Mitigate* project, we design and host crowdsourced open innovation challenges for young people age 13–18 to develop methods for mitigating global climate change. The challenges invite students to participate in a global effort to reduce emissions, to engage with peers and with scientists about real science, and to take agency for their own learning.

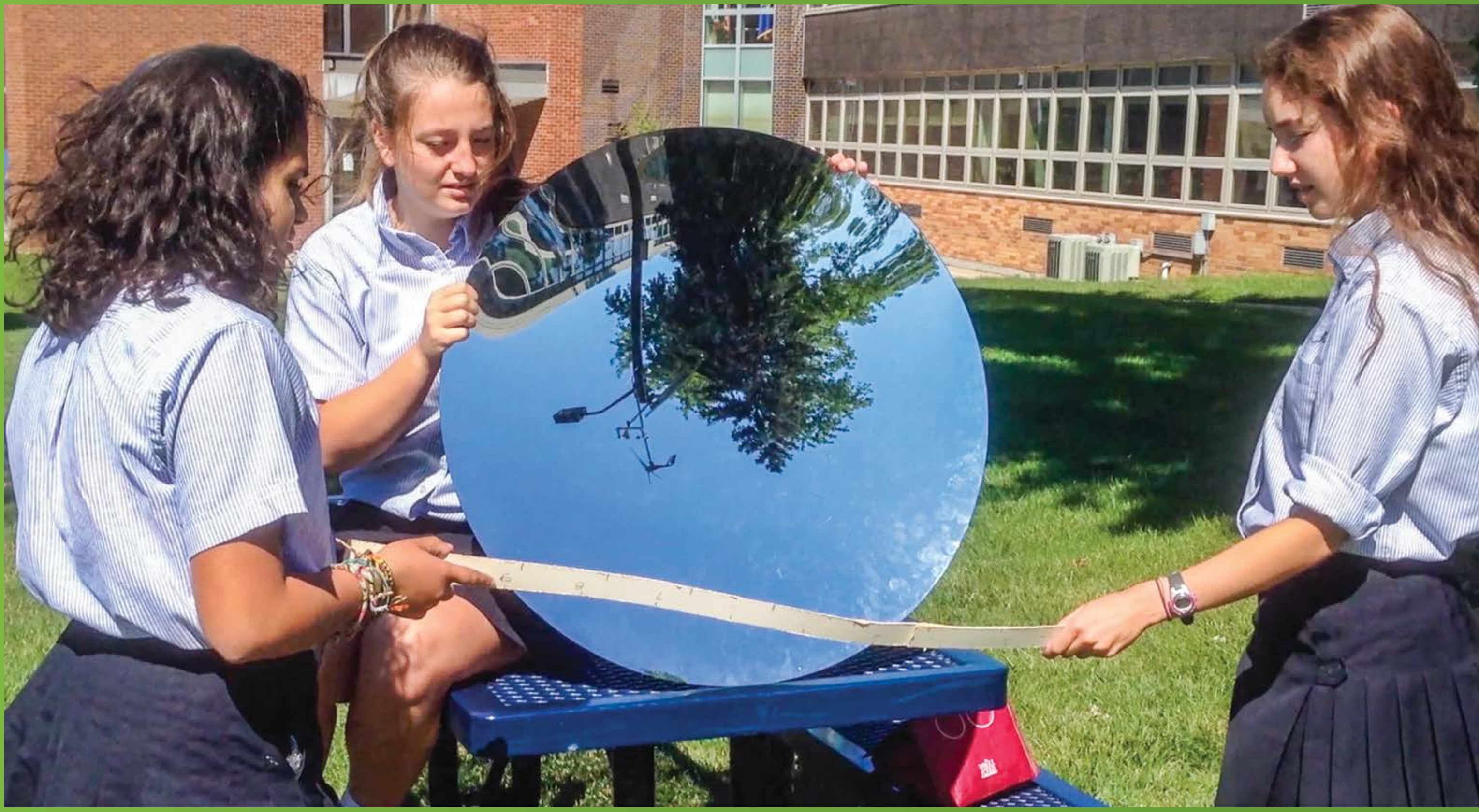

Figure 1. Testing a parabolic reflector to enhance the efficiency of a novel apparatus to produce biochar.

In this article, we describe the results from two pilot Challenges that ran in 2013–2014, and 2014–2015 (Puttick & Drayton, 2017). In total, 10 students participated from two international schools (China and Lebanon), one parochial school, one private school and 80 from public schools across the US. The median age was 16 and median grade level was 10th grade. Twenty-eight teams submitted videos and accompanying science papers (see their videos at innovatepilot.videohall.com and Innovate2015.videohall.com).

The Challenges are widely publicized through postings on social media, listservs, and emails. The project website features breaking stories about exciting mitigation research projects that inspire creativity and seed ideas from news outlets, links to YouTube videos, and reports in popular science blogs.

Teams develop a climate change solution over a period of several weeks, helped by a local coach (usually their teacher) with execution, problem-solving, and logistical challenges. They present their project through videos and papers posted to an online video forum, where each is judged by a panel of four scientists. Teams are awarded cash prizes for innovation, best video/paper presentation, and most engaged in discussion in the online forum. In addition, a community choice award is given to the project that receives the most likes.

*Innovate to Mitigate* is designed to engage a broad diversity of participants working collaboratively. They work in teams in an open-ended, goal-oriented way, yet the parameters of the challenge and a suite of tools and resources structure the problem space. The online cross-platform competition fully integrates social media to build a youth-led learning community around mitigation. It draws on crowdsourcing to elicit the best thinking of participant teams as many real-world crowdsourcing efforts do (King & Lakhani, 2013). It uses social media to support student participation, just as social media have increasingly facilitated the work of media practicing scientists (Henry, 2016).

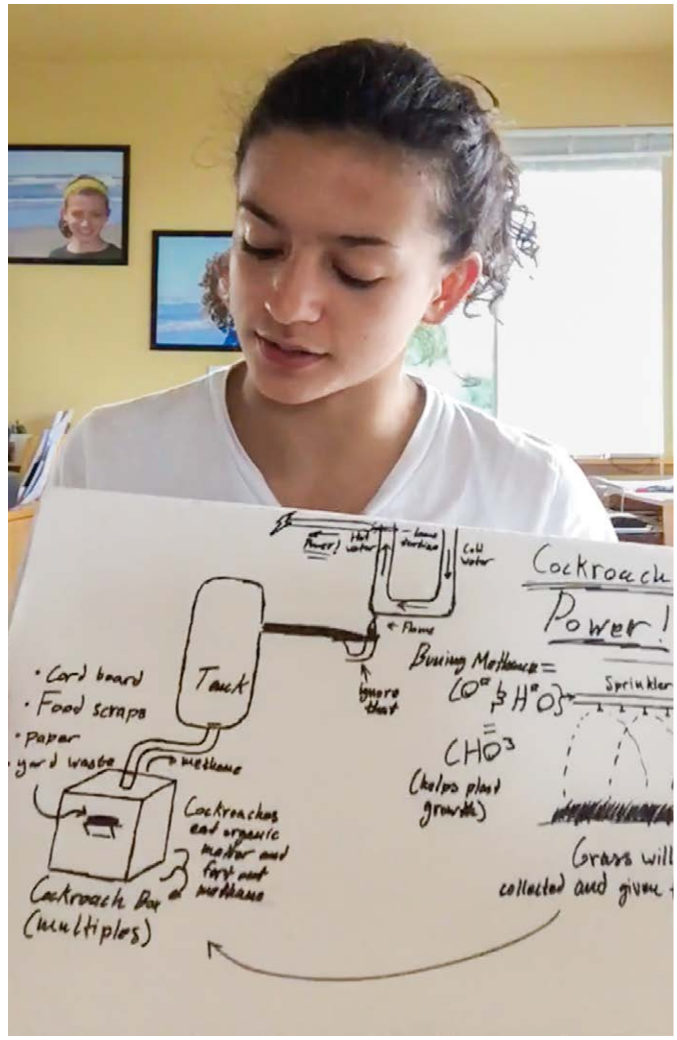


**Figure 2. Design sketch of a model system designed to collect methane produced by cockroaches in the lab.**

## Enhancing Learning Through Networking and Collaboration

We wondered how *Innovate to Mitigate* participants might benefit from working in a setting in which they interact with key collaborators (other teams, coaches, and experts). We were aware that researchers note several benefits that participants receive in traditional poster sessions: receiving feedback and networking with others, promoting communication skills and collaboration between group members, and creative assessment opportunities (Stroud & Falk 2015 provide several valuable references in this connection, including Aust & Kinnick, 1996; Johnson & Green, 2007; Stegemann & Sutton-Brady, 2009; Sisak, 1997). We are seeing that these same benefits accrue to participants in the *Innovate* competition.

Caring about and mitigating climate change motivated roughly half the students to participate, while half participated as part of a course designed by their teacher.

Twenty percent said they were motivated by the prize money. When asked to rate their learning at the end of the competition, an overwhelming majority of students reported that they had learned a moderate or great amount about climate change and about the specific area of their project. Over half of them provided detailed information about how the project experience had enhanced their learning.

***At the beginning of the project I knew some general problems our world is facing and the basics of photosynthesis that occurs in plants.***

***Now, as a result of the project, I know how artificial leaves are crafted and mimic photosynthesis, and how they can be used to mitigate $CO_2$ emissions.***

In both pilot studies, we gave teams access to Videohall, a social-media style platform designed for the sharing of posters and presentations. In reviewing interactions that occurred on the platform, our team was able to capture snapshots of deep learning across a wide range of domains. For example, the Photoelectrics team of three 10th graders in Maryland designed transparent solar cells as smartphone covers to continually charge phones during use, thus obviating the need for a plug-in charger. One of the judges raised a concern about the efficiency of the solar cell indoors, where light levels are lower. A team member responded:

> *[...] Some sources of indoor lighting, particularly halogen lamps, incandescent lamps, can emit a varied amount of ultraviolet energy providing some charge to the device. In fact, 70% of energy emitted by incandescent lamps consist of infrared energy. Common fluorescent lamps used today can still transfer ultraviolet energy with variable strengths depending on the proximity to the lamp. While the charge provided indoors will not be nearly as powerful as direct sunlight, some electric charge can be generated from indoor lamps and light leaking in through windows.*

Another judge singled out the Photoelectrics team and explained their high rating for this project, writing:

> *The solar smartphone screen project did a very good job of integrating a power use problem into current technology.*

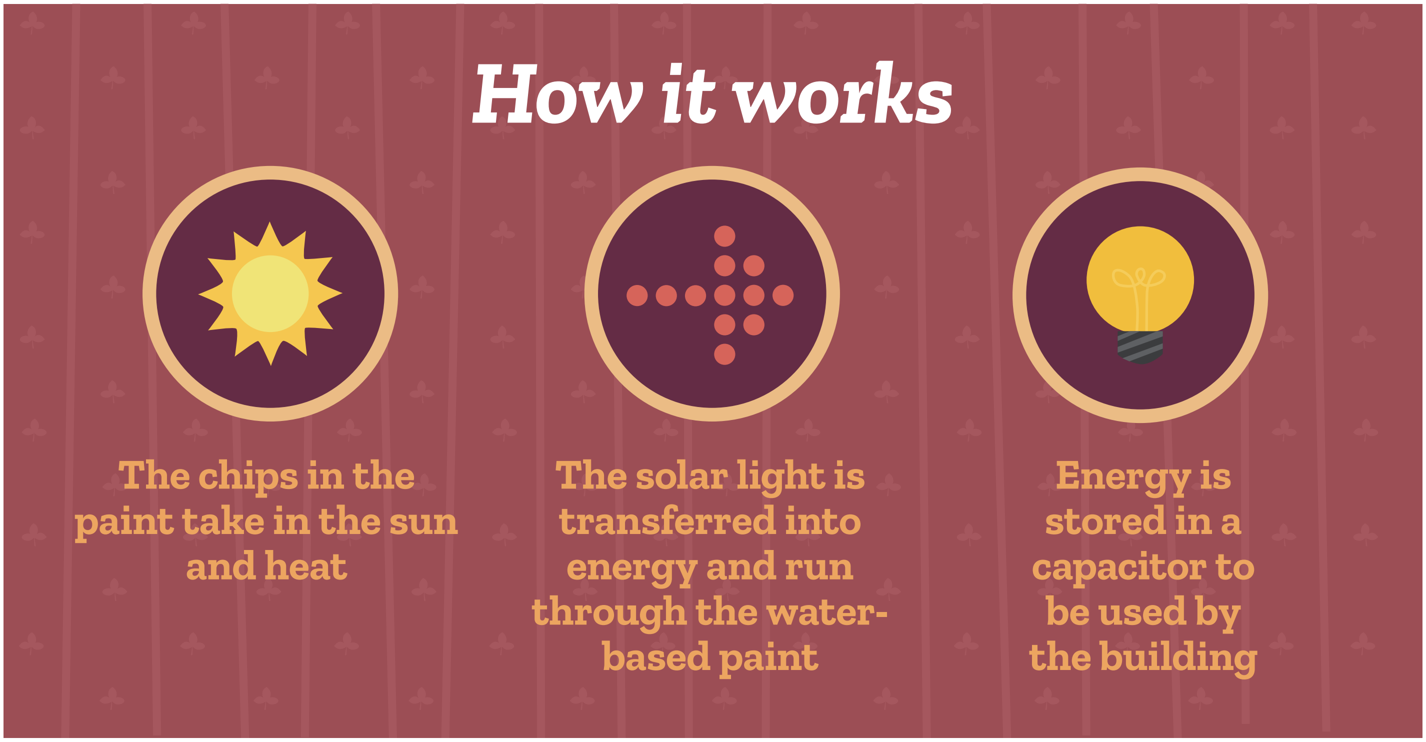


Figure 3. Explaining how a mix of graphene, water-based paint, and tiny solar panel “chips” will generate energy to power a building. Solar energy is conducted from the solar chips via the paint to a capacitor.

*If they were able to implement this, it would circumvent people forgetting to use an external solar charger. Depending on power usage, I could see this technology, in conjunction with more efficient batteries, potentially removing the need to charge smartphones.*

Overall, the power of the competition as a learning environment was amply demonstrated by the caliber of the projects the students produced, the depth of learning revealed in their posters, videos, and discussions, and the students' own ratings of the competition experience. Furthermore, the pilots showed the potential for this type of competition to generate fresh and innovative ideas for carbon mitigation.

## The "Intelligent Life Forms" team

We were able to get a close look at one *Innovate* team in TERC's neighborhood in a different competition year (Drayton & Puttick, 2018). The Intelligent Life-forms (ILF) team included four 12th grade students, Ricardo, Safran, Casper, and Kenzhi, at a public school in the Boston area. (Participants and teachers are given pseudonyms to protect their identities.) They were mentored by their chemistry teacher, Mr. Bowman, and advised by Mr. Schuyle, a research chemist.

ILF decided to explore strategies to capture-and-sequester $CO_2$. To begin, they were interested in the role of marine algae in taking up $CO_2$. These experimental organisms were attractive for several reasons: They might be able to work with them in the lab, there were ways to estimate biomass or other parameters from water samples—and it would mean that they had to take some field trips to the seashore!

With their advisor's assistance, ILF became interested in the effects of $CO_2$ when absorbed in seawater. This topic in turn helped them to understand a lot more about $CO_2$ chemistry and the process of taking measurements in very complex systems.

They finally chose to propose a specific mitigation methodology: adding iron as a fertilizer to sea water to stimulate the growth of algae, and thereby capture more $CO_2$, using a robotic delivery device. This proposal led them into

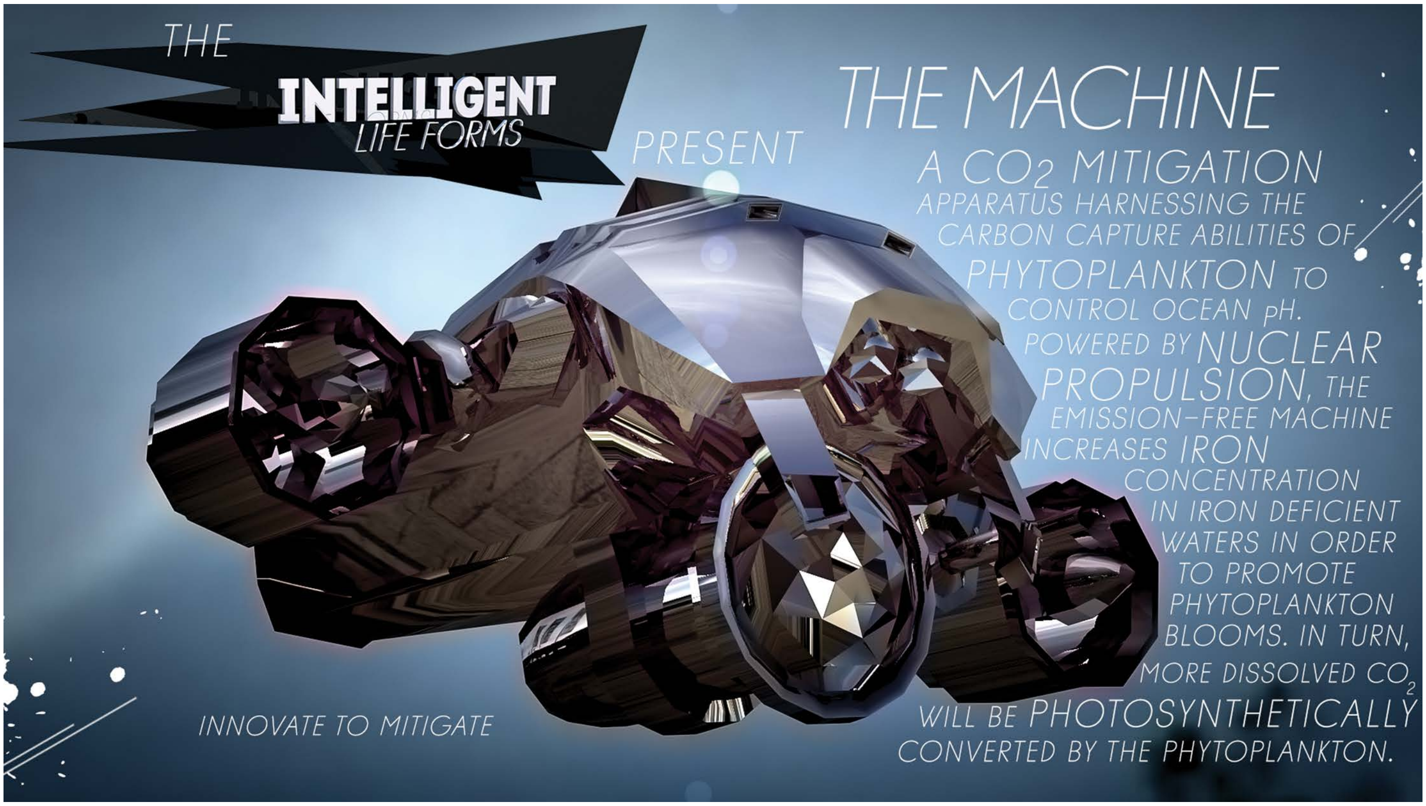


**Figure 4. An idealized representation of the miniature robotic devices proposed by the Intelligent Life Forms team to capture algae produced via iron fertilization of the ocean.**

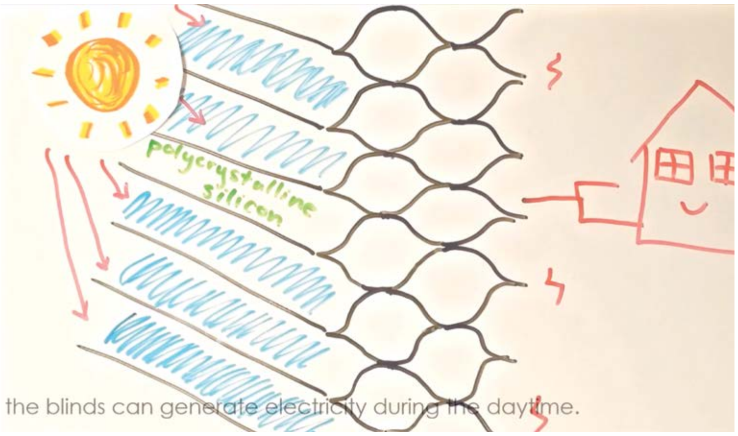


**Figure 5. High efficiency solar cells, embedded in insulating blinds, capture energy.**


**Figure 6. Artificial leaves mimic the process of photosynthesis to capture $CO_2$.**

areas beyond their capacities (Figure 4). Although unable to build and test their algae capture robot, ILF had learned considerable amounts of science content, and skill with science practices.

In addition to learning concepts in chemistry, climate change and mitigation, and science communication, they learned skills and practices associated with the development and evaluation of concepts and methodologies necessary for a research project. More importantly, they had experiences that are not usually included in the evaluation of science learning, yet have long been understood in the philosophy of science as essential elements in successful inquiry:

- Metacognitive processes and tool development necessary to define the inquiry in terms of questions, theoretical issues at play, and methodologies. As Mr. Schuyle advised:

  *What I like about Science is that it allows one to discover for oneself the truth. We do not rely on another's interpretation of the truth, which is second hand. [...] I propose we set about the sequestration question/issue with open minds. I can assure you, if we are earnest, whatever we learn through our efforts, [...] will affect us directly — intellectually, emotionally, or physically.*

- The deployment of imagination. In a progress report, the team wrote:

  *We all had many ideas ranging from a machine in the atmosphere or ocean that could filter $CO_2$, to using algae to clean of $CO_2$ in the ocean.*

- The productive uses of failure. In response to a judge's query in the discussion forum, Casper wrote:

  *The most frustrating part of the project definitely centered around our early trouble with setting a baseline for pH changes in water due to $CO_2$. Even with the help of our Chemistry teacher and one of his colleagues who works in a lab in the area, we were unable to get accurate results for much of the early part of this school year. In the end we succeeded, but the experimentation route was seeming less viable as the deadline approached.*

## Conclusion

Understanding learning in the context of a science competition can help us understand the consequences of including such learning contexts in the ecosystem of school-based science.

Pat (a teacher who required her class to participate) wrote us in an email in 2015:

> *Initially, I thought that my students didn't have time to compete and do all that we wanted them to [...] I really have to praise my students for all the work they did on this project, the majority of which was outside of class. They'd discuss each other's entries in the hall, including those from other schools, and really learned a lot about environmental issues. I am really hopeful that you plan to continue with the competition this year.*

Offering a rich, real world challenge that can accommodate divergent thinking in a “knowledge community” builds critical social skills and cultural competencies for youth, e.g., collective intelligence (the ability to pool knowledge with others toward a common goal), judgment (the ability to evaluate the reliability and credibility of sources), and negotiation (the ability to “travel across diverse communities, discerning and respecting multiple perspectives, and grasping and following alternative norms”) (Jenkins 2009, p. 106).

The competition attracted and motivated teens to enter and resulted in sustained engagement in deep science learning. Taken together, our results show that teams crossed disciplinary boundaries as they chose concepts from chemistry, engineering, mathematics or biology to address the mitigation challenge. They addressed a wide diversity of topics ranging from biomimicry for artificial photosynthesis, to decarbonization of fossil fuels, to social media campaigns for reducing energy use, or improving transportation efficiency.

## Upcoming Challenges

Visit the project website for details about upcoming challenges in 2020 and beyond.

- **innovatetomitigate.org**

Sign up to let us know about possible interest, and follow us on Facebook.

- **facebook.com/innovatetomitigate**

## Acknowledgements

The authors would like to acknowledge the contributions of our TERC colleagues Abe Drayton and Santiago Gasca, as well as the teachers, students, scientists, and other mentors who made the project come alive. We also wish to acknowledge the work of Joni Falk and the STEM for All Videohall team at TERC, whose Videohall hosted our pilot competitions.

## Author Bios

**Brian Drayton**, Ph.D., co-directs the Center for School Reform at TERC. A plant ecologist working in science education since the 1980s, projects have included research and development on electronic communities of practice and on inquiry learning and technology use in secondary school classrooms. Other work (with Gillian Puttick and others), as part of the TERC Life Sciences Group includes curriculum development and research in life science, ecology, and climate change education. Current interests focus on the nature of communities as science educators, and on discourse processes and cognition about science and on processes of curriculum design.

**Gilly Puttick**, Ph.D., has a broad background in biology and biology education and has worked as an educational researcher and curriculum developer at TERC for almost 30 years. As a PI and co-PI, she has directed many federally-funded education research and development projects, most recently focused on climate change education. She focuses her efforts on bringing fresh scientific discoveries to formal and informal settings through designing, developing and researching curriculum, programs, and activities for students and teachers. With Drayton, she is co-leader of the Life Sciences Group at TERC.

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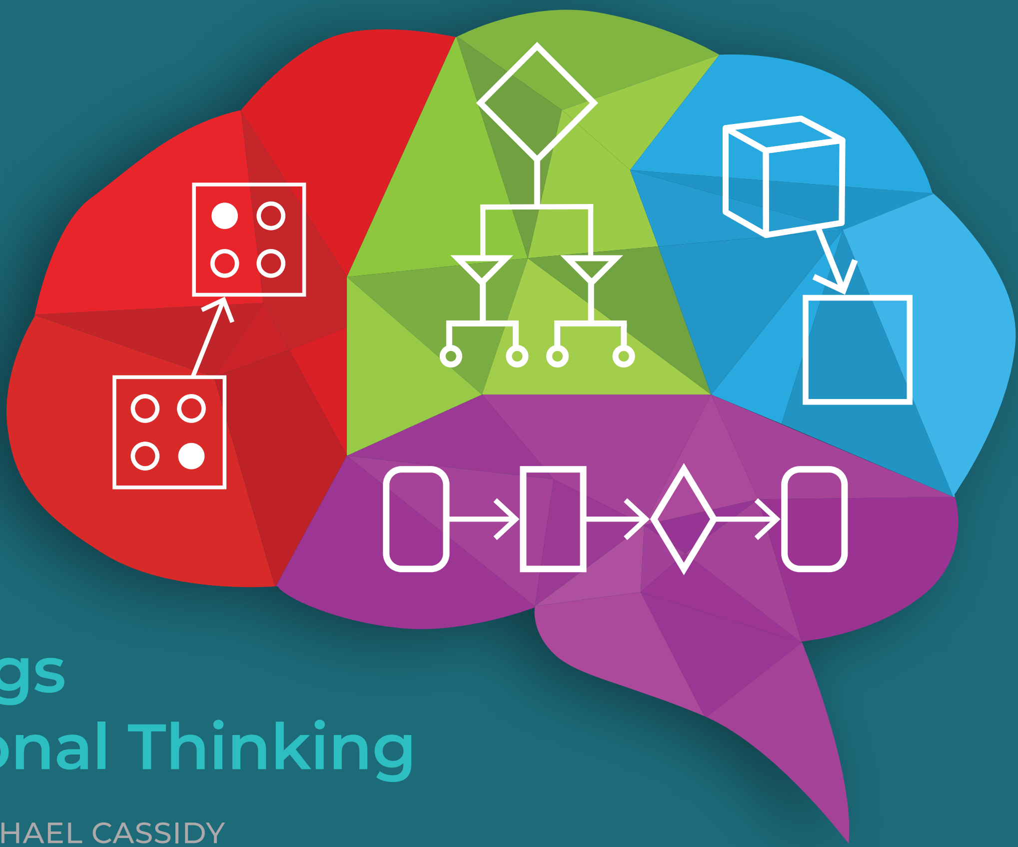
# What is CT?



## Teachers' Understandings of Computational Thinking

BY TEON EDWARDS AND MICHAEL CASSIDY

Computational thinking (CT) is a hot topic in education. The idea of CT in education can be traced back to the work of Papert in 1980, with the term most often associated with Wing from 2006. But only over the last five years or so has CT become a common focus in education ... and at TERC, where multiple projects continue to conduct research on CT learning.

Four years ago, in May 2016, a group of TERC staff interested in CT started meeting together monthly. The idea was for the people in the group to help educate, inform, and support each other in a community of practice. In these meetings, some common issues and areas of interest were identified, including a serious shared challenge—a general lack of agreement around the definition of CT within the research field, amongst ourselves, and with our teachers. Indeed, despite efforts within the field over the years, there is still no unanimous definition of computational thinking or agreement how to best apply it in K-12 classrooms (Malyn-Smith et al., 2018).

## Teachers as Part of the Discussion

In Wing's (2006) seminal piece, she stated CT is "a fundamental skill for everyone, not just for computer scientists. To reading, writing and arithmetic, we should add computational thinking to every child's analytical ability" (p. 33).

Her comments sparked a debate among computer scientists, educational researchers, and other academics about what computational thinking is and what it is not, as well as how to best integrate CT into education. However, classroom teachers are typically not part of the discussion.

We believe that teachers need to be represented more in this CT conversation. As practitioners, they are actually bringing the computational practices, terminology, and experiences into the classroom, as well as noticing students' ability to take up these practices and concepts. In addition, teachers are the ones most impacted by the resulting definitions, changes to and development of related standards and curricular materials, and the research directions.

Thus, the two of us decided to go beyond the monthly discussions to gain a better understanding of how teachers are thinking about CT. We wanted to scope out the landscape of CT education, especially as it relates to clear communication between educators and researchers.

As part of this, we sought teacher input in various ways, including via a survey. This survey included three ways of eliciting the teachers' understandings of the definition of CT:

1. An open-end text box,
2. A select-up-to-5 list of central terms, and
3. A pick one definition.

We distributed the survey over multiple National Science Teacher Association listservs, via research colleagues, and through TERC's Communications Department. Overall, 202 teachers responded enough to be included in our analysis, with an approximately equal number from each school level (elementary, middle, and high school). Here's some of what they had to say.

## Open-Ended Text Box

Early in the survey, we asked respondents, "If a parent asked you to explain what computational thinking is, what would you say?" We provided an open-ended text box for their answers.

Not too surprising to us, many teachers said they did not know (n = 21 or 9%), even though they were responding to a survey specifically about computational thinking in education. Also not surprisingly, **problem solving** was the most commonly referenced idea (n = 42 or 18%). Problem solving is core to most computational thinking definitions, as you'll see later. It was also core to a number of the teachers' responses:

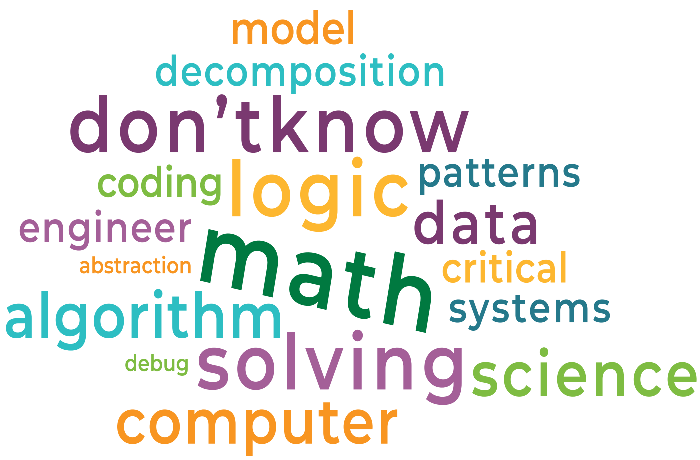
> *To think using Algorithms and **solve problems**.*
>
> *Creating and then using feedback from a system to **problem solve** using logical steps to come up with a working solution.*
>
> *How to **solve problems** using algorithms and logic.*
>
> *Computational thinking is a mindset that has to do with developing **problem-solving skills** where you are logically interweaving data analysis to develop solutions.*
>
> *Computational thinking is the process of identifying a **problem**, thinking of a **solution**, and ensuring that solution can be carried out and repeated by another.*

However, there were also a few surprises. For example, we found it interesting so many **science** teachers noted CT as related to **mathematics** (n = 30 or 13%). We were also surprised that coding and computers weren't more prominent,

### CT-Related Projects at TERC

If you'd like to see our research in action, multiple TERC projects have and continue to conduct research on CT learning. Here are a few that could be of interest:

- **CodePlay**
  terc.edu/projects/codeplay
- **GrACE**
  SEEC.terc.edu/GrACE
- **IDATA**
  terc.edu/projects/innovators-developing-accessible-tools-for-astronomy
- **INFACT**
  INFACT.terc.edu (Coming soon!)
- **Zoombinis**
  terc.edu/terc_products/zoombinis




**Word cloud of the terms most used by teachers in the open-ended "explain what computational thinking is" survey question.**

with only n = 9 or 4% referencing coding or programming and only n = 19 or 8% referencing use of a computer.

There's a lot of debate around how central coding is to computational thinking, especially when dealing with CT assessments, but a connection to computers is pretty standard. For example, teacher math- and computer-related responses included the following:

> *Mathematical and logical thinking.*
>
> *Computational thinking is understanding how computers and mathematical tools are used to analyze data and do simulations.*
>
> *Thinking like a mathematician, problem solving.*
>
> *Being able to express your ideas in a way that a computer could understand.*
>
> *All I would know to say is it is similar to activities that are done on Code.org.*
>
> *Trying to think logically like a computer would, or in a way that you can communicate with a computer.*

## Select-Up-To-5 List of Central Terms

Of course, open-ended answers, while rich, are also hard to analyze, so we asked a series of subsequent questions, while not allowing the respondents to backtrack to their written answers. For example, we asked, "Which of the following terms do you consider most central to computational thinking?" with a select-up-to-five list of eleven terms commonly used in CT literature:

1. Abstraction
2. Algorithmic Thinking
3. Coding or Programming
4. Data Representation
5. Debugging or Troubleshooting
6. Logical Thinking
7. Modeling and Simulation
8. Pattern Recognition
9. Problem Decomposition
10. Problem Solving
11. Systems Thinking.

Within the 148 respondents to this question, the terms selected ranged widely, with problem solving again quite common (71%) and coding or programming less common

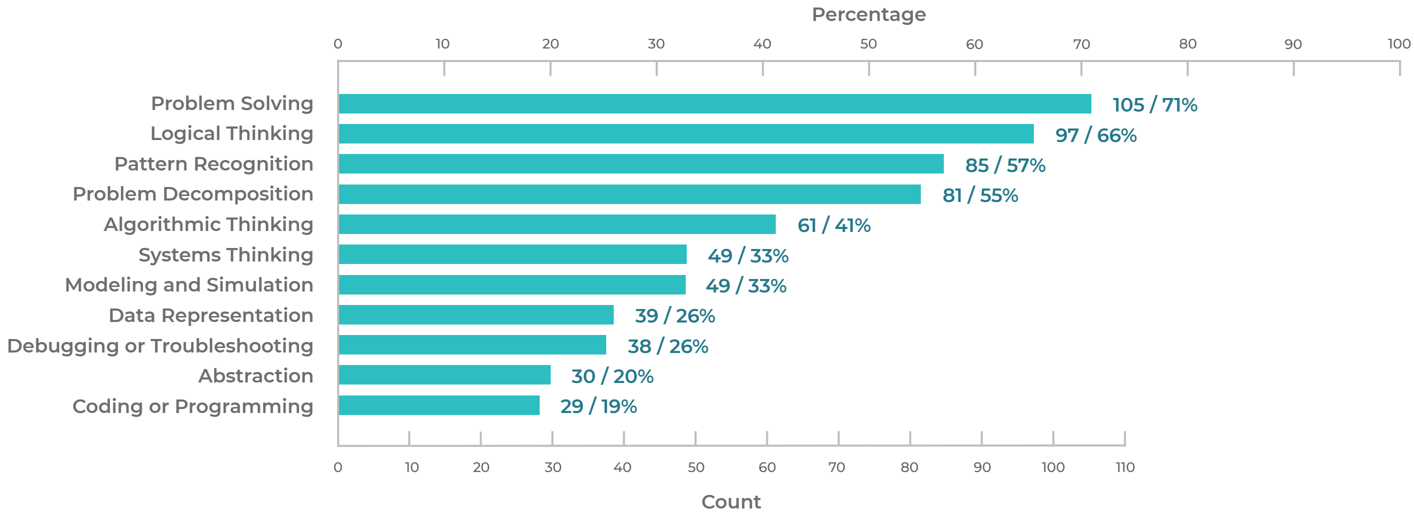
**OTHER INTERESTING FINDINGS:**

### Ability Ratings

The survey addressed an array of questions, not all related to just the definition of CT. We also asked teachers to rate which common CT skills they can teach and their beliefs about what their students can do. We found all teachers were much more confident in their teaching abilities than in their beliefs of their students' skills. For example, 97% of respondents indicated they had at least an "adequate" ability to teach problem solving, while 80% of them indicated they believed their students' had at least an "adequate" ability with it. Contrast this with 52% and 38%, respectively, for coding or programming.

Our results showed that grade level did not matter across these skills, except in two areas: algorithmic thinking and programming. In both areas, elementary school teachers were more confident in both their teaching ability and their students' ability. We hypothesize the elementary teachers were more confident in both areas because of differing complexity of these terms at each grade level, as well as the tools that are used (e.g., block-based vs. text-based programming).

Table 1: Terms teachers (n = 148) selected as most central to CT




(20%) than we anticipated, based on our interactions with teachers through our projects. [A comparison of the teachers' and researchers' selections might prove an interesting area of additional exploration.]

## Pick One Definition

The survey finally offered a select set of commonly used definitions and asked respondents (n=147) to pick the one they identified with most.

- Wikipedia citing Wing (2014): "Computational thinking is the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out."
- ISTE (International Society for Technology in Education): "Computational thinking is a problem-solving process that includes (but is not limited to) formulating problems, analyzing and representing data, and algorithmic thinking."
- Wing (2006): "Computational thinking involves solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science."
- CSTA (Computer Science Teachers Association): "Computational thinking refers to the thought processes involved in expressing solutions as computational steps or algorithms that can be carried out by a computer."
- Created by Authors: "Computational thinking is what you do when you use a computer."

Respondents picked the ISTE description most at 50%, with Wing (2014) from Wikipedia at 26%, Wing (2006) at 14%, CSTA at 9%, and—thank goodness—our made-up definition at only 1%. The high selection of the ISTE description is not surprising, as many of the respondents mentioned ISTE when asked which conference(s) related to CT they had attended. Additionally, during interviews (conducted separately from the survey), teachers mentioned ISTE as the most common place they saw CT referenced.

## What's This All Mean?

We believe an understanding of computational thinking and its roles that is shared by researchers and teachers is vital to furthering the field of CT education research and development. By this, we do NOT mean a single definition; instead, we are striving for shared understandings about different ways we think and talk about CT as well-focused, shared understandings within the scope of an individual project or effort. Such shared understandings are important to clear communication, to logical research findings, to appropriate assessments, and so much more.

Our survey and this article are very small attempts at building toward these shared understandings. For us, a main take-away is simply a refinement of where we were when we started this work: *When we, as education researchers, are talking to and working with teachers around CT, we need to remember we aren't all necessarily speaking the same language.* For any project, early sharing of all parties' perspectives and reaching a shared agreement on what will be meant for the work together are always important. These principles are even more important in computational thinking education.

As the debates over CT continue, let's all try to have teachers, and the realities of their classrooms, be part of the conversation.

## Acknowledgements

Thank you to NSTA for the use of their listservs and to the teachers who participated in the survey. We would also like to thank TERC for funding this project.

## Author Bios

**Teon Edwards** is co-founder of and a lead designer for the Educational Gaming Environments group (EdGE) at TERC. With a background in astrophysics, mathematics, and education with a focus on the use of technology and multimedia for learning, she has spent over 20 years developing science curricula, experiences, tools, and games for both formal and informal settings. She was production manager for the re-release of the award-winning computational thinking game *Zoombinis*, and she has since worked on multiple NSF, Department of Education, and TERC-funded projects researching CT learning across grades 3-8, including the nation-wide *Zoombinis Implementation Study*, the Research-Practice Partnership (RPP) *CodePlay* with the Braintree, MA school district, and *INFACT: Include Neurodiversity in Foundational and Applied Computational Thinking*, as well as the pilot study addressed in this article.

**Michael Cassidy**, Ph.D,. is a senior researcher and member of the STEM Education Evaluation Center at TERC. His research and evaluation work draw on professional experiences as a middle and elementary school science and English language arts teacher in Title I schools in Mobile, AL. His current work focuses on computational thinking, engineering education, robotics, and evaluation of mathematics and science intervention programs. He is especially interested in teachers' perspectives about their professional learning, the impact of STEM educational programs on learning opportunities, particularly for members of underrepresented groups, and application of computational thinking across content areas.

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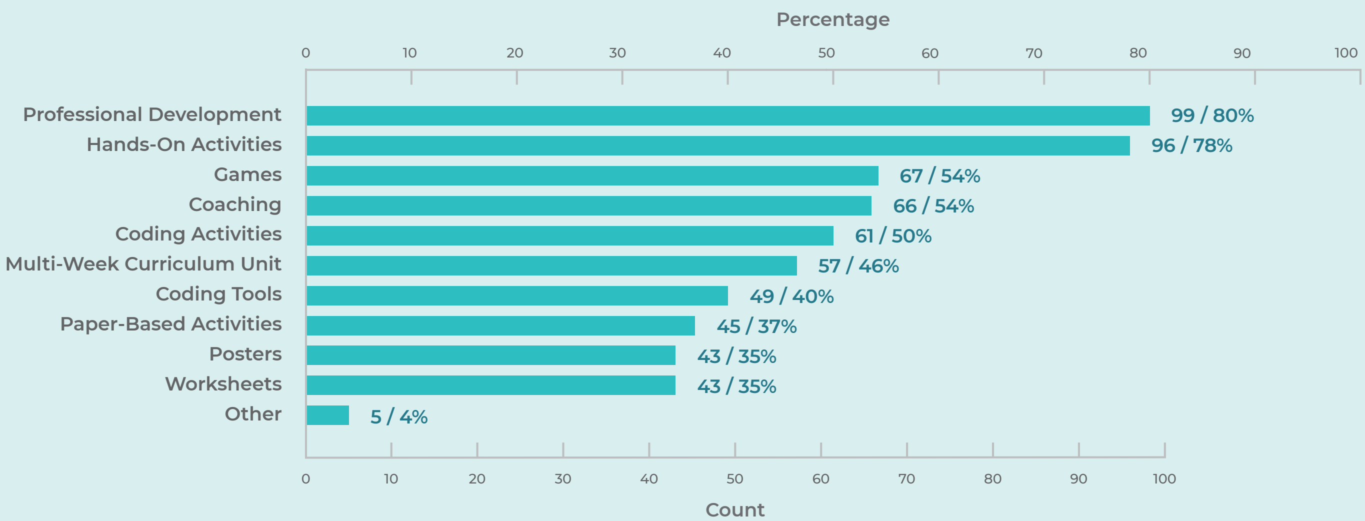
**OTHER INTERESTING FINDINGS:**

### Desired Supports or Materials

The survey also asked teachers what types of supports or materials they wanted to help integrate computational thinking practices into their teaching.

**Table 2: Supports and materials teachers (n = 123) selected as most desirable to help them integrate CT.**



# The TERC Scholars Program

## Broadening Participation in STEM Education

**Diversifying the science, technology, engineering, and mathematics (STEM) workforce is a unique challenge that begins with who and how we educate in STEM. It requires both acknowledging the past, to unravel systemic injustices that have historically excluded marginalized communities from participation in STEM education, and looking to the future, to cultivate new, dynamic educational opportunities for diverse involvement.**


The TERC Scholars Program (TSP) was established in 2017, in conjunction with Wheelock College (now under Boston University), to encourage underrepresented minority college students to envision futures for themselves in STEM fields. TSP offers paid internships and customized mentoring to STEM and non-STEM majors and engages them in TERC's ongoing research work. The internships expose students to the plethora of STEM careers available to them. TERC scholars:

- Engage in interdisciplinary research that promotes the importance of STEM literacy for all learners
- Receive guidance and counseling about graduate career and professional development opportunities
- Learn essential research skills and methodologies to supplement TERC's expansive body of STEM education research
- Interact with fellow STEM educators and researchers to contribute their unique perspectives to the larger STEM ecosystem
- Investigate and communicate the ways in which their research project can create a broader impact through transformative social justice

The 2018-2019 academic year boasted an outstanding cohort of TERC Scholars working on an array of innovative National Science Foundation (NSF) projects. Some of their accomplishments include presenting their work at the University of Colorado–Boulder and Tufts University, co-authoring an article in a peer-reviewed journal, and receiving a thank-you message from U.S. Congresswoman Ayanna Pressley.

In the following pages two scholars, Nicole Shearer and Katie Yao, share first-hand accounts of their experiences in TSP. Through their diligent efforts, and the invaluable guidance and support of their TERC mentors, TERC Scholars like Nicole and Katie are expanding their own horizons and embracing the significance of broadening participation in STEM education to include everyone.

The TERC Scholars Program would especially like to thank Dr. Detris Adelabu, Director of the Boston University Emerging Scholars Program, and Dr. Mia Ong, Senior Research Scientist at TERC, for their unwavering support, wisdom, and recruitment efforts throughout the years.

The TERC Scholars Program gratefully appreciates the time, knowledge, and commitment of all mentors and principal investigators, TERC President Laurie Brennan, and especially of Marlene Mitchell for her instrumental work as the TSP Administrator.

To learn more about the program, including current and past TERC Scholars' work, please visit: **terc.edu/work-with-us/terc-scholars-intership-program**

Stephen D. Alkins, Ph.D., is the Diversity, Equity, and Inclusion Officer at TERC and Director of the TERC Scholars Program.

# Youth Advocacy Through PD for Paraeducators

Nicole Shearer

I was a senior at Wheelock College/Boston University graduating with a B.S. in social work when I interned at TERC. I supported *Doing the Math with Paraeducators* (NSF #1621151), a project which focuses on professional development of mathematics paraeducators in grades K–3. My TSP mentors were Karen-Mutch Jones and Judy Storeygard.

The project's goal is to provide and study professional development that builds the confidence of paraeducators by helping them strengthen their mathematics knowledge and teaching strategies. Paraeducators—formerly referred to as teacher aides, teaching assistants, or instructional aides—work alongside teachers, often supporting challenging students and filling critical teacher shortages. Paraeducators are often required to teach mathematics content without being provided the knowledge or supervision they need to be effective. *Doing the Math* supports them to be able to enhance the mathematics learning experience of their students, who come from a wide range of experiences and backgrounds.

We conducted the project in the Boston Public Schools and focused on grades K–3, where the largest numbers of paras are employed. Because I have previous research knowledge from interning with other TERC projects, I was able to assume an active research role, helping collect and code data from surveys, post-observation debriefings, written reflections, and individual interviews.

My contributions to data analysis were most substantial. I carried out the entire process for coding qualitative data, including creating and refining a codebook that could be used by the entire project team in the future. I also participated in the classroom, supporting the professional development sessions, where I enjoyed building relationships with some of the paras.

I was happy to see that findings from this project showed increased para confidence in math knowledge and teaching practices. For instance, we were able to track the para growth in differentiating instruction to address student strengths and needs, which came from their own knowledge of the different ways to solve the same problem. One para stated that the program helped her "as an educator to push my students more and also it helped me to learn". We also found that the paras built a learning community together, and that the discussions they had with each other during the professional development continued in their own schools.

As a future social worker, my passion is really youth advocacy. I was able to see the project from the perspective of young students who have disabilities or who for whom English is a second language. Paras often encounter these students, and it's important that they feel empowered to support them. Supporting young students in mathematics is particularly important, as early mathematical skills have been shown to be powerful predictors of later academic achievement (Stipek et al., 2012). It was meaningful to me to have this opportunity to help strengthen paraeducators in this way, and to know that the project will broaden learning opportunities and access for young learners of many backgrounds and abilities.

## References

Stipek, D., Schoenfeld, A., & Gomby, D. (2012). Math matters: Even for little kids. *Education Week*.

## Project info

*Doing the Math wih Paraeducators*: **terc.edu/projects/paraeducators**

# Improving College and Workplace Environments for Underrepresented Groups

Katie Yao

During my internship, I was a junior at Boston University majoring in Health Science and minoring in public health and business administration. At TERC, I worked on two projects with Mia Ong, Nuria Jaumot-Pascual, Audrey Martinez-Gudapakkam, and Christina Bebe. *Literature Analysis and Synthesis of Women of Color in Technology and Computing* (LASOW, NSF # 1760845) focuses on the experiences of women of color in technology and computing. *Native Women and Two-Spirit Individuals Higher Education: A Photo Elicitation Study of Persistence* (NAWC2) is a study that uses photo elicitation to determine success and barriers for Native students at institutions of higher education.

The goals of both projects include contributing to the understanding of factors that allow students of color to persist in their fields, identifying gaps in knowledge, and recommending solutions to retain women of color in STEM and Native students in higher education.

My role on the team was to assist in the process of creating a literature synthesis for LASOW. This included writing brief analytic memos on existing literature on women in computing and technology at institutions of higher education and workplaces, as well as learning how to code literature. During this time, I learned various terms that were needed to complete an attributes form, such as sample size and data collection method, for each piece of literature and research methods that social scientists use to gather and analyze data.

Additionally, completing the attributes form was a daunting task at first because we had to define ambiguous terms to ensure that everyone on the team was completing the form systematically and uniformly.

While reading literature for both projects, I noticed many similarities between the experiences of women of color in STEM and Native American students (men and women) in higher education. Both groups faced overt and covert racism on campus and in the workplace, which made them seek social and cultural groups that allowed them a safe space to share their struggles and successes. They also want to give back to their community because they want to make their friends and family proud as well as to be a role model for children.

Women of color and Native students mentioned a mentor who acted as an advocate, sponsor, and/or role model, which helped them navigate their institutions or careers. I thoroughly enjoyed reading each piece of literature because as a first-generation college student, I can attest to the struggles of the participants in the studies and I found the testimonies of the participants to be incredibly touching. It also made me realize the numerous changes that institutions need to enact to ensure an equitable environment for students of color to succeed.

Prior to my internship at TERC, I was on the pre-medical track, but I have since transitioned to pursue other interests in business and law. After reading literature on women of color in STEM and Native students' experiences in higher education, I realized that many of my peers in college had similar experiences mentioned in the studies. I think I want to continue helping to improve the college and workplace environment for underrepresented groups.

### Project Information:

LASOW— **terc.edu/projects/lasow**

NAWC2— **terc.edu/projects/nawc2**

# The LEAP Forward:

## An Interview with Maria Blanton

**In conjunction with researchers at the University of Texas at Austin and the University of Wisconsin-Madison, TERC has developed LEAP, Learning through an Early Algebra Progression. We were able to sit down with Maria Blanton, a Senior Scientist at TERC, to discuss the program.**

### What brought you to this project? Why did you think there was a need for an early algebra curriculum?

We recognized that, generally, students are not prepared for the kind of math that they are doing in middle school and high school, and that algebra is really the gatekeeper for post-secondary education and entering the job market. We found that by spending just a little bit of time building early algebraic concepts in elementary grades, we can significantly improve children's algebra readiness as they enter middle grades, and this has the potential to transform their success in school mathematics.

### What makes LEAP different than other elementary programs?

LEAP is a supplemental program entirely focused on building early algebraic thinking, yet it does so by connecting with and deepening children's understanding of arithmetic. It uses a series of tasks and activities to help children build their understanding of key algebraic concepts and practices over time. It is a first-of-its-kind resource that delivers authentic early algebra experiences for all learners: the lessons are coherent; the concepts are connected; the content is accessible; and the outcomes are transformative, increasing children's readiness for learning formal algebraic concepts in later grades.

### The title of the program talks about an "Early Algebra Progression." What does this mean?

LEAP is based on extensive research in elementary classrooms that helped us design lessons that reflect how children's algebraic thinking develops. We set out to build a program that would help students develop their understanding of early algebraic concepts gradually, over time. The lessons are connected across the grades, reflecting a progression of increasingly sophisticated concepts and practices. We focus on three big ideas: Equivalence, Expressions, Equations and Inequalities; Generalized Arithmetic; and Functional Thinking. These big ideas help us build the core algebraic thinking practices of generalizing, representing, justifying, and reasoning with mathematical structure and relationships.


### What does a LEAP lesson look like?

Each LEAP lesson provides the background information that teachers need to support learning in the classroom. We identify the outcomes of the lesson and also help teachers understand the rationale for the tasks that children will be engaged in. We start the lesson with a Jumpstart question to engage the students, and then provide instructions and prompts that help teachers guide children through the tasks. At the end of the lesson, a Review and Discuss prompt allows teachers to quickly check student understanding and provide correction and support when necessary.

### Tell us a bit more about the research behind the LEAP program.

The LEAP program is based on over a decade of research in elementary classrooms. All lessons have undergone years of testing in authentic settings in order to understand how children make sense of lesson tasks and activities and how to support teachers in successfully implementing the program. Lessons are packed with research-based insights into how children think about particular concepts, the difficulties they might have, and how teachers can address these.

### You've tested this with a lot of students in the classroom. What has been the student response to the lessons?

Students' capacity for algebraic thinking—and their engagement with LEAP lessons— has always amazed us. A critical feature of each LEAP lesson is building rich classroom conversations around algebraic ideas. We have found that all children bring interesting ideas to classroom conversations and have the capacity to think algebraically. With the LEAP program, children are excited to learn because lessons are based on the investigation of ideas, and they each have a contribution to make.

### What type of training does a teacher need to implement the lessons in LEAP?

We recommend that teachers start with a two-day training session, with follow-up sessions throughout the year as they implement LEAP. The goal of the professional development is threefold: (1) develop and strengthen teachers' knowledge of algebraic thinking practices and core concepts; (2) understand how students make sense of these concepts and practices and how to respond to their ideas in instruction; and (3) explore teaching practices that increase students' engagement with core algebraic concepts and practices.

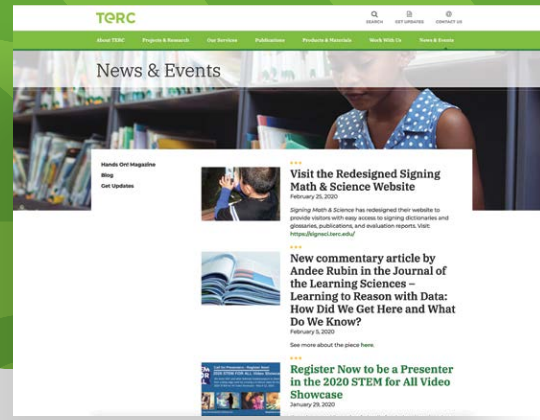
### How can I learn more about LEAP and using the program in my school or district?

We have partnered with Didax to publish the instructional materials for the LEAP curriculum. Currently there are resources available for grades 3, 4, and 5. They are being published in the Spring of 2020. Visit **www.didax.com/leap** for more information about the books and professional development and to order.

Funded by the National Science Foundation and the United States Department of Education.

**Maria Blanton** is a Senior Scientist at TERC in Cambridge, MA. Her primary research interests include teaching and learning algebra in the elementary grades. Her expertise has led to numerous federally-funded research projects and national and international presentations and publications (in, e.g., Journal for Research in Mathematics Education, American Educational Research Journal, Educational Studies in Mathematics, Teaching Children Mathematics). She is co-editor of the research volumes Algebra in the Early Grades (2008, Taylor/Francis) and Teaching and Learning Proof Across the Grades (2009, Routledge), author of Algebra and the Elementary Classroom: Transforming Thinking, Transforming Practice (2008, Heinemann), and co-author of Developing Essential Understanding of Algebraic Thinking for Teaching Mathematics in Grades 3–5 (2011, NCTM) and Teaching with Mathematical Argument: Strategies for Supporting Everyday Instruction (2018, Heinemann). She has served as Chair of the Editorial Panel for the Journal for Research in Mathematics Education and Chair of the Special Interest Group for Research in Mathematics Education (SIG-RME) of AERA. Dr. Blanton is currently PI of US DoE and NSF-funded projects investigating Grades K-5 children's understanding of algebraic thinking and the impacts of sustained early algebra education on children's algebra-readiness.

# What's New at TERC.edu?




**Thanks to the overhaul to our website, finding the information you're most interested in has never been easier. Looking for the latest news? Click on "News and Events" in the top menu.**

terc.edu/news-events

Here's what's been going on!

### New commentary article by Andee Rubin in the *Journal of the Learning Sciences*

**Learning to Reason with Data: How Did We Get Here and What Do We Know?**

In this commentary, I emphasize five critical aspects of working with data that have emerged from this body of work: context, variability, aggregate, visualization, and inference. I believe these will remain relevant in spite of the addition of new techniques to our arsenal of methods for making meaning using data and can form the basis for ongoing collaborations among learning scientists, statistics educators, and data science educators.

### New Report by TEAM-UP (including TERC's Mia Ong)

**The Time Is Now: Systemic Changes to Increase African Americans with Bachelor's Degrees in Physics and Astronomy**

In this groundbreaking report, TEAM-UP has uncovered long-term systemic issues within the physics and astronomy communities that contribute to the underrepresentation of African Americans in these fields and makes important, actionable recommendations for community wide efforts to reverse this trend.

### Teacher Leaders are Working Together Online to Improve Schools, Effect Policy, and Re-envision the Future of STEM Teaching and Learning

TERC announces the launch of the STEM Teacher Leadership Network, funded by the National Science Foundation. They invite teacher leaders, researchers and administrators to join this quickly growing online community to effect change in STEM teaching and learning.

### 2020 STEM for All Video Showcase — Learning from Research and Practice

**May 5th-12th: Save the Dates**

**stemforall2020.videohall.com**

You are invited to take part in a free, interactive, week-long video showcase event that will feature over 200 federally funded projects. Projects showcase their innovations in Science, Mathematics, Engineering and Computer Science education in formal and informal settings. View videos of interest, post queries and feedback to the presenters, and vote for your favorites. Thousands of researchers, K-12 educators, higher ed faculty, administrators, policy makers, aspiring investigators, graduate students, and parents will take part.


### TERC Blog is here!

**Announcing our new blog**

Get a first look at newly-funded innovative research projects. Dive deep into STEM education topics. Read interviews of past and present staff members from the TERC history project. You can do all this and more by reading TERC's NEW monthly blog!

Visit terc.edu/blog to check it out.

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