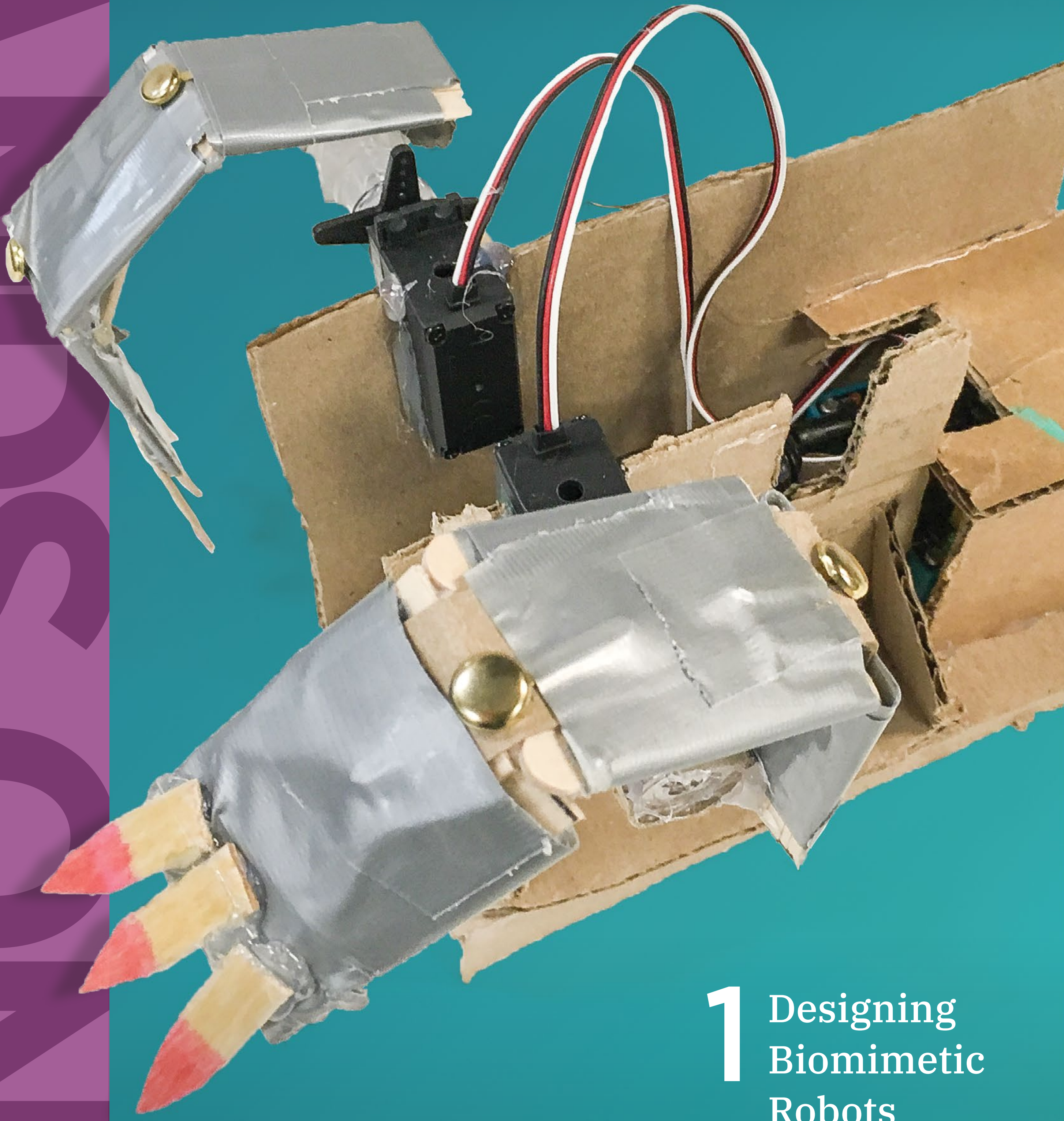
HANDS ON

A magazine for mathematics and science educators

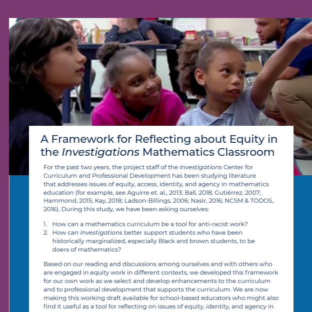
TERC

FALL 2021



1 Designing Biomimetic Robots

CONTENTS



Letter from the President

STEM learning takes place everywhere by leveraging the natural world, makerspaces, and everyday activities. At TERC, our research and development efforts strive to expand learners' perception of themselves as science and math thinkers. Opportunities to learn in multiple settings such as science centers, museums, classrooms, and within the family unit enrich the learning experience and help to build a strong STEM identity throughout the learner's journey.

In *Designing Biomimetic Robots*, middle school students use what they learn about animals and how they accomplish different tasks in nature to build and program a robot. Biomimicry is the study of nature to inspire design. It is used here to expose learners to its value in solving real world problems such as recovering from a natural disaster. During the activities students practice computational thinking, scientific reasoning, and engineering design skills through an interdisciplinary approach with science, engineering, and computers. In this article you will also learn about research outcomes through this growing partnership between TERC and Tufts University's Center for Engineering Education and Outreach (CEEO).

The authors of *Authentically Integrating Mathematics into Making Experiences* address the challenge that learners' early experiences in math learning can develop into negative perceptions of mathematics and their own math abilities. Mathematics is often portrayed as a disconnected set of formulas or procedures that have little to do with the creative, flexible ways that math is used in both STEM and our daily lives. 'Making' may be a key strategy allowing educators and researchers to rethink how mathematics is presented thus enhancing the math experience for children and adults, helping them develop into STEM thinkers and doers.

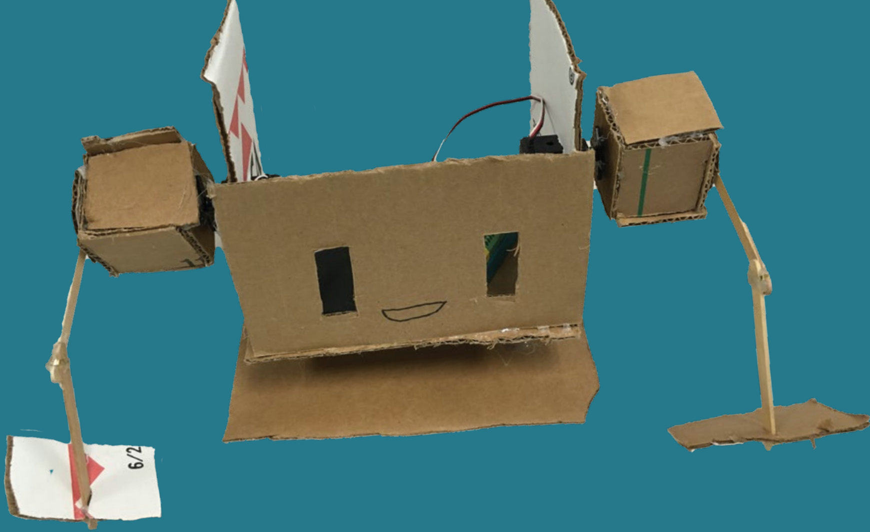
In *Bringing Math Talk Home*, you will read about the experience of a young woman in a non-STEM major, who joined TERC via the TERC Scholar Program (TSP). She worked on TERC's *Aprendiendo de familias: Learning Math Talk* project, coordinating with Spanish-speaking families in the Boston area to expand and support mathematics education for Pre-K students, engaging Spanish-speaking parents and their young children in Math Talk. Sharing lived-experiences with project participants helped this TSP scholar strengthen her contributions to the research and gave her a valuable lens into how important it is to have parents involved in their young children's learning, especially in math.

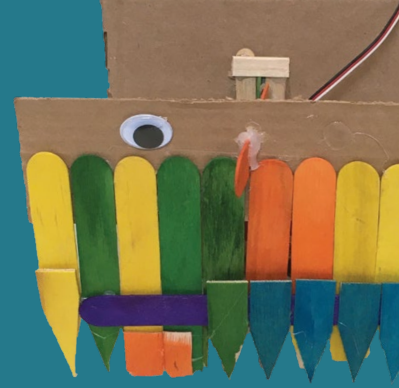
Laurie

Laurie Brennan, *President*

Editor: Valerie Martin
Copyeditor: Amanda Smith
Administrative Support: Katie Stokinger
Design: Jason Fairchild, Truesdale Group
Director of Brand Strategy & Communication: Jaclyn Parks

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.

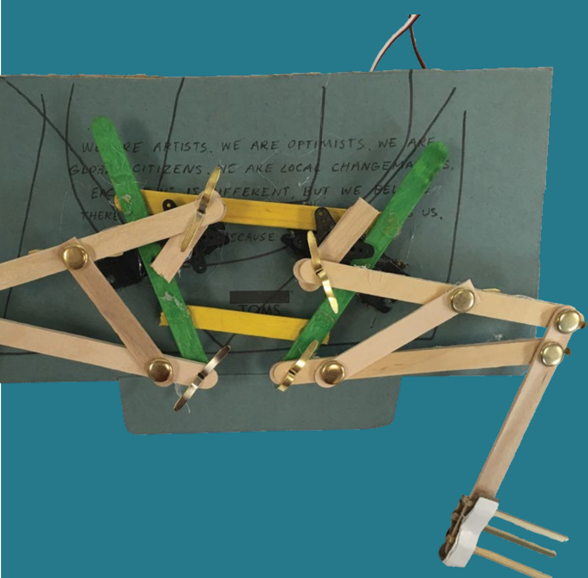


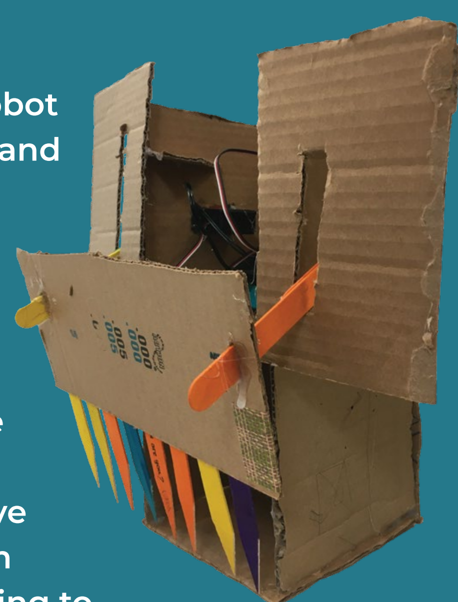


Designing Biomimetic Robots

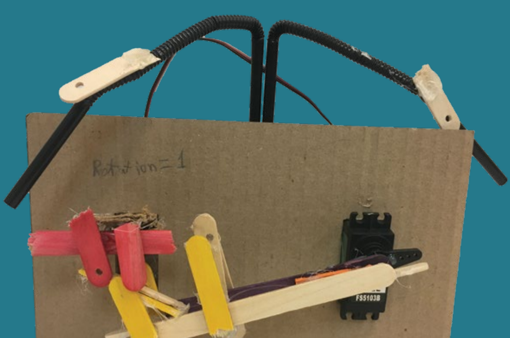
Animals as Inspiration

By the Designing BioRobots Team





Your task … is to build a robot that can dig through dirt and rubble, to help in disaster scenarios — like after an earthquake, when it's too dangerous to send in people. To do this, you will use biomimicry — the study of nature to inspire design. Some animals have body parts that help them dig efficiently. You are going to learn about four animals that are well adapted for digging. Then you will design a robot that is inspired by the body parts that help the animal dig.



BioRobots
DESIGNING BIOMIMETIC ROBOTS

In most middle schools, learning is segregated by discipline—science in one class, and engineering or computing in another. Yet recent trends in science and engineering education suggest this approach is outdated. Students need to use skills and practices from multiple subject areas to solve problems. *Designing Biomimetic Robots* is a curriculum designed to support middle school students in thinking across biology, engineering, and robotics, providing the foundation for an innovative approach to interdisciplinary education.

Developed by researchers at TERC and Tufts University's Center for Engineering Education and Outreach (CEEO) and funded by the National Science Foundation (#1742127), the *Designing Biomimetic Robots* curriculum challenges middle school students to learn about biomimicry by interweaving engineering, biology, robotics, and computer programming concepts through a series of engaging, practical, and fun tasks.

What is Biomimicry?

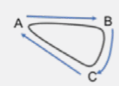
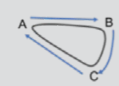
Human designers and engineers have long been drawing inspiration from nature's successful designs. Biomimicry is the word used to describe the study of nature to inspire design.

The *Designing Biomimetic Robots* curriculum is designed to engage middle school students in using ideas from animal structure and function to build a biomimetic robot. In this course of study, students will study the natural world to learn how animals accomplish different tasks, then design and build a robot inspired by what they learned. In the process, students will have an opportunity to practice computational thinking, scientific reasoning, and engineering design skills, and learn how to build and program a robot.

Interdisciplinary learning

The curriculum, revised over multiple iterations (Bernstein et al., in press) asks students to design a search and rescue robot adapted for digging as part of potential recovery efforts in the event of a disaster. Students begin by studying the internal and external structures of four animals well adapted to digging in different ways: pangolins (hook and pull diggers), gophers (scratch diggers), mole rats (chisel tooth diggers), and moles (humeral rotation diggers). Based on their biology research, students then choose an animal to mimic. The instructional materials guide them through the process of studying animal structures and functions, and then designing and building a digging robot that reflects what they learned about their digging animal. Included templates, prompts and other scaffolding materials carry student teams through the steps of framing the problem, decomposing the structures

Figure 1 | Student animal analysis

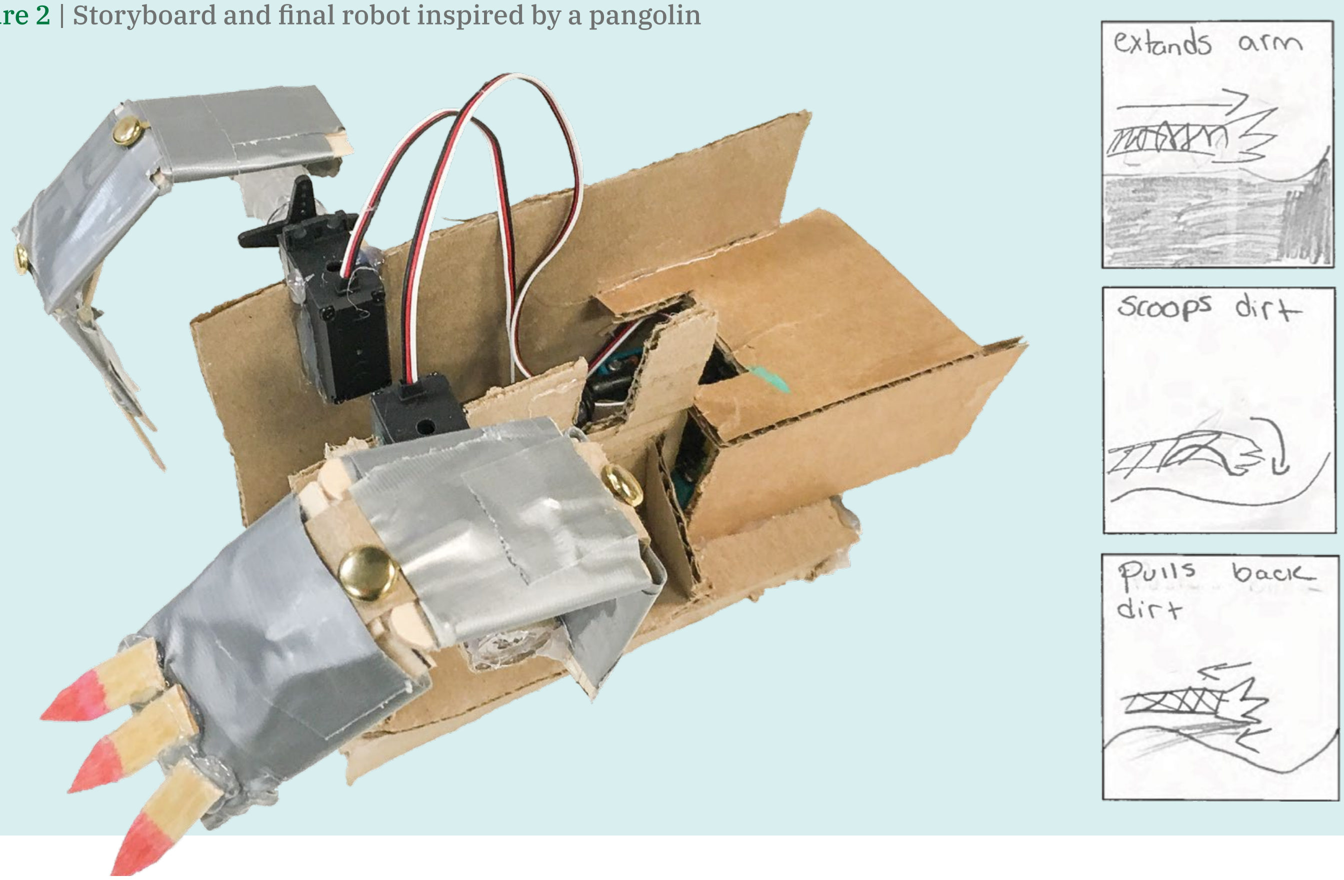
What does it use to dig?	What adjectives describe the part?	What verbs tell what that part does?	How does the structure move ?	Draw arrows that show path of body part
1. Claw	*Stiff, hard material, not flexible, long and curved*	*Breaks hard dirt*	*Forward and down*	
2. Paw	*Stiff, covered in scales*	*Protects against hard dirt, bones support claws*	*Forward and down*	
3. Arm	*Short, muscular*	*Provides force for digging*	*Same as paw and claws*	

What structure is the main digging structure? *Claws*

What structure or structures help that part or are connected to it (secondary structures)? *Paws, bones and muscles of legs and shoulders*

Chisel tooth, scratch, rotation, hook and pull are kinds of digging that students research in developing their robots. This example from the curriculum demonstrates the type of animal analysis students complete during BioRobots.

Figure 2 | Storyboard and final robot inspired by a pangolin



and functions that help animals dig, and abstracting that understanding to inspire their robot design. Students then spend several sessions making that design a reality through multiple rounds of building, testing, and documenting their findings to refine and improve upon their final product.

The curriculum includes approximately 15 hours of classroom activities as well as building guides, links to multimedia resources, printable student worksheets, lists of materials needed, and teacher tips throughout. An introduction for the teacher discusses problem-based learning; suggested instructional approaches, including formative evaluation; and information on alignment with the Next Generation Science Standards. Lesson plans support student engagement in disciplinary practices such as developing and using models, generating design solutions, abstraction and decomposition.

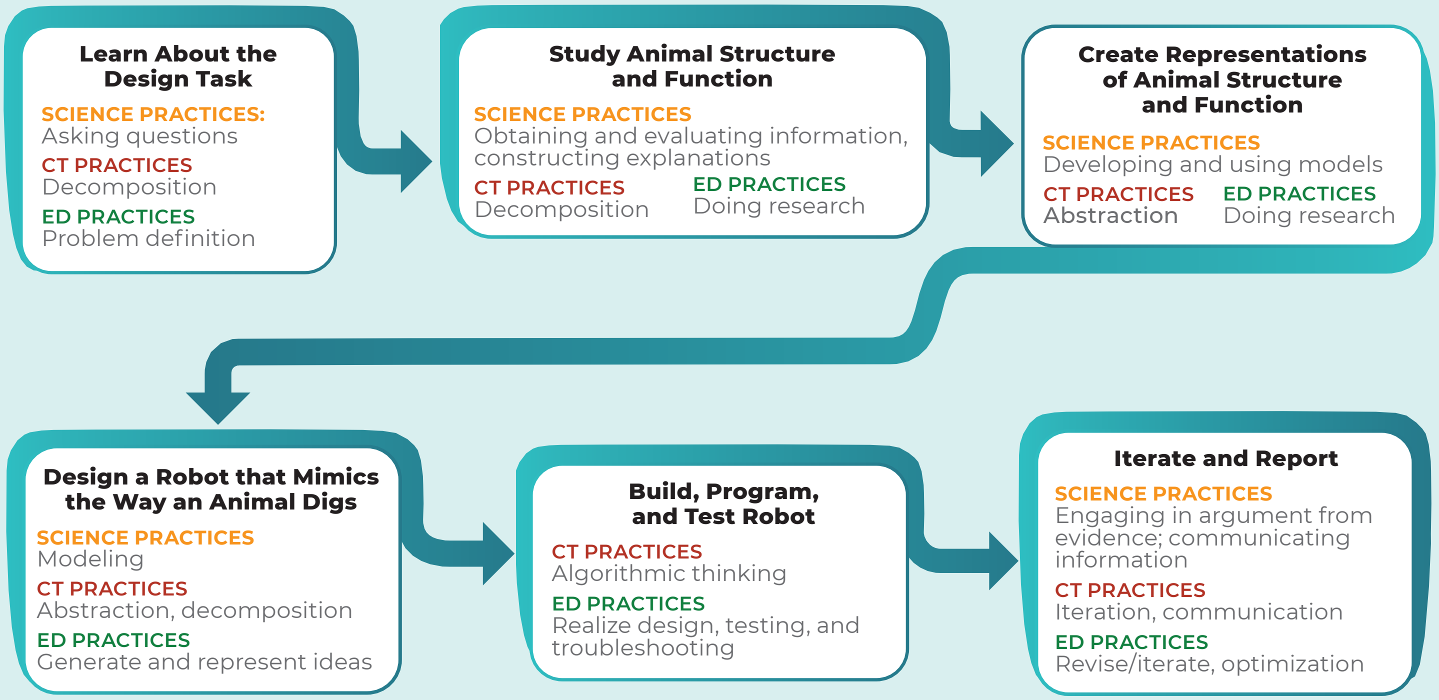
Figure 3 aligns the science practices, engineering design (ED) practices, and computational thinking (CT) practices with the main activities that students participate in during the curriculum.

Research

The project's goal was to create and research an integrated learning experience that incorporated biology, engineering, and computing. Research on the curriculum's effectiveness was guided by one overarching question: *How does the* Designing Biomimetic Robots *learning environment support student engagement in interdisciplinary learning?*

The research team from TERC and Tufts piloted the curriculum in classrooms across multiple states, in urban and suburban school districts with diverse student demographics. Over three years, 22 middle school teachers and nearly 800 students participated in piloting the curriculum. Science, engineering, and technology teachers participating in the pilot program completed professional development before implementing the curriculum and suggested valuable improvements to shape the curriculum further.

Figure 3 | Aligning science practices, engineering design, and computational thinking processes



During this pilot period, researchers collected student-based evidence, using a case-study approach to assess the effectiveness of *Designing Biomimetic Robots* at meeting its learning objectives. A pre-post assessment showed that the curriculum helped students improve knowledge, practices, and skills in engineering, science, and computational thinking. In interviews, students were readily able to describe the ways in which their robots were and were not biomimetic (i.e., mapping animal structure/function analysis to robot design), provide a rationale for the design choices they made, and describe the iterations in their engineering design process.

The activities in the BioRobots curriculum provided students with new ways to encounter, apply, and express their disciplinary knowledge (Shaw et al., 2020). *Designing Biomimetic Robots* provides an easily deliverable structure to bring robotics construction activities into science and engineering courses and makes this type of study more accessible for students with a broad range of academic experiences.

How to access the curriculum

Visit **terc.edu/biorobots** to download the curriculum, resources, and a one-hour activity.

Acknowledgements

This material is based upon work supported by the National Science Foundation under Grant Number 1742127. Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

The BioRobots team is grateful to the teachers and students who participated in the project. We thank the teachers for their collaboration, and the students for designing and creating these robots.

Project Team

Debra Bernstein, Ph.D., is a Senior Researcher in the STEM Education Evaluation Center (SEEC) at TERC, a non-profit research and development organization. Her research interests include curriculum design, implementation, and learning opportunities arising from the integration of technology design activities into K-12 and informal learning settings.

Michael Cassidy, Ph.D., is a Senior Researcher at TERC. His work focuses on teacher professional learning, computational thinking, engineering education, robotics, and evaluation of mathematics and science intervention programs.

Ethan Danahy, Ph.D., is a Research Associate Professor at the Center for Engineering Education and Outreach (CEEO) with secondary appointment in the Department of Computer Science within the School of Engineering at Tufts University. His research focuses on the design, implementation, and evaluation of different educational technologies, ranging from software and hardware to interfaces and environments.

Gillian Puttick, Ph.D., is a Senior Scientist at TERC. Her research focuses on designing, developing and testing inquiry-based curriculum, programs and activities for students and teachers that introduce fresh scientific discoveries to the classroom.

Fay Shaw, Ph.D., is currently a postdoctoral scholar at Tufts CEEO. Her research focuses on designing and incorporating educational technologies in formal and informal learning environments. Within this project, she has focused on artifact analysis.

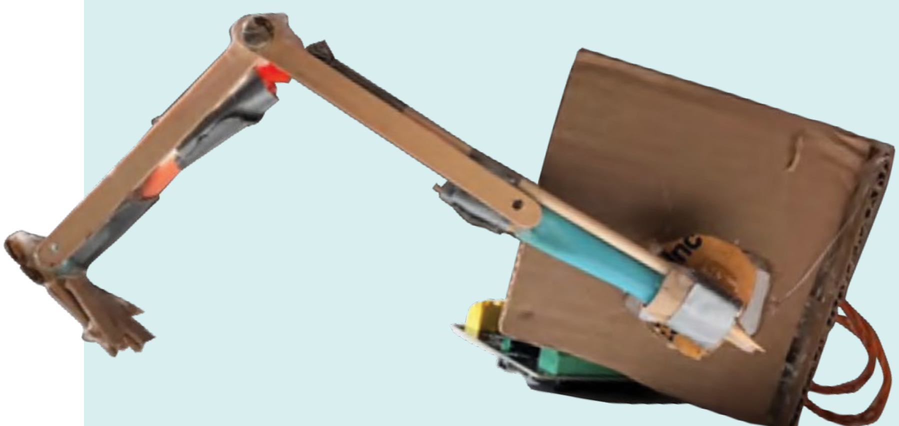
Kristen Wendell, Ph.D., is an associate professor in mechanical engineering and education at Tufts University. Her research focuses on supporting productive and equitable classroom discourse in engineering learning experiences in K-12, undergraduate, and teacher education contexts.

References

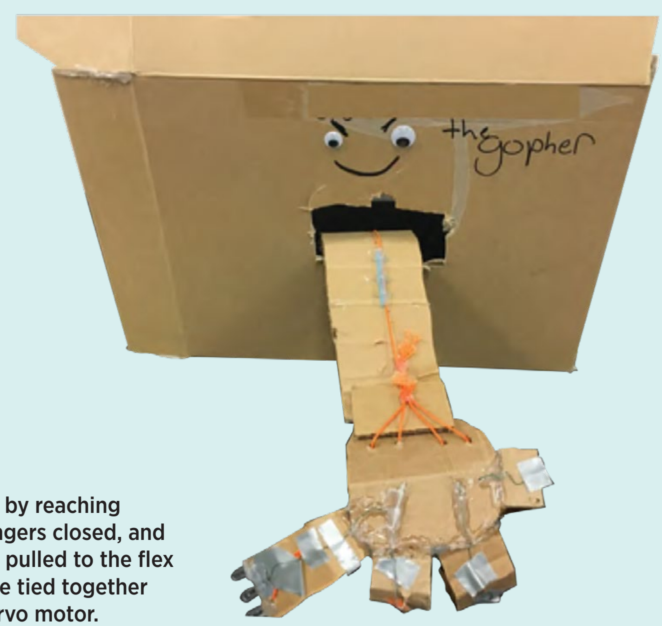
Bernstein, D., Puttick, G., Wendell, K., Shaw, F., Danahy, E., & Cassidy, M. (in press). Designing Biomimetic Robots: Iterative Development of an Integrated Technology Design Curriculum. *Educational Technology Research and Development*.

Shaw, F., Kshirsagar, K., Wendell, K., Danahy, E., Bernstein, D., Puttick, G., & Cassidy, M. (2020). Characterizing student artifacts in a multi-disciplinary biomimicry and robotics unit. In *Proceedings of FabLearn 2020*.

Figure 4 | Scratch Digging



This robot mimics the gopher's strong arms and claws moving in a circular motion driven by a rotation motor.



This robot mimics scratch digging by reaching forward with its arm, flexing its fingers closed, and pulling back rubble. Each finger is pulled to the flex by a cable drive and the strings are tied together to pull all at once by a position servo motor.

Photo courtesy of Children's Museum of Pittsburgh

Authentically Integrating Mathematics into Making Experiences

Math in the Making Project

ANDEE RUBIN AND SCOTT PATTISON

©Adobe Stock

While knowledge of mathematics is essential to every aspect of science, engineering, and technology, decades of research tell a consistent story: **mathematics education in the United States is a barrier rather than a gateway to children's engagement with STEM careers.** Early in their lives, many children develop **negative perceptions of mathematics and their own math abilities** (Denner et al., 2019; Ganley & Lubienski, 2016; Jiang et al., 2020).

As mathematics becomes a more essential part of STEM classes and topics, these children can lose interest in STEM or doubt that they have the ability to pursue a STEM-related career (Cohen & Kelly, 2020; Dika & D'Amico, 2016; Jiang et al., 2020). To make matters worse, math in school is often portrayed as a disconnected set of formulas or procedures that have little to do with the creative, flexible ways that math is used in both STEM and our daily lives (Gutiérrez, 2018; NCTM, 2018; Pattison et al., 2017).

As STEM educators and researchers who have been working in the field of informal STEM education for many years, we believe that a key strategy for addressing these challenges is to rethink how mathematics is presented and thus expand the range of children and adults who see themselves as competent mathematical thinkers. One promising context for engaging new learners in mathematics lies in the growing maker movement across the country. At its core, "making" provides opportunities for individuals to take charge of their own learning, design and create based on their interests and passions, and develop their identities as STEM thinkers and doers (Calabrese Barton et al., 2017; Martin, 2015; Vossoughi & Bevan, 2014).[1] We believe these making experiences are rich with opportunities for mathematical reasoning that often go unrecognized by both participants and educators.

Since 2015, we have been exploring this potential through the *Math in the Making* initiative. The work focuses particularly on children's museums and science centers, many of which have developed maker spaces and programs over the last decade. In this article, we share insights from our most recent round of research. To begin, we consider the fundamental question of what it means to authentically integrate mathematics with making.

What is Authentic Integration?

A core commitment of the *Math in the Making* project has been to ensure that mathematics is integrated *authentically* into the making experience and is *consequential* to the goals of the maker. But what do we mean by "authentic integration"? How do we promote math reasoning and reflection without detracting from the freedom inherent in making experiences?

As an example, first imagine that a middle school math teacher is working on a lesson on algebraic relationships. She has introduced the idea of balancing the two sides of an equation and is looking for a way to make this concept more intuitive. At the local science center, she saw a mobile sculpture exhibit that encouraged visitors to explore the multiplicative relationship among weight, distance, and force on each side of the fulcrum (see **Figure 1**). Working with educators from the museum, the teacher builds a smaller version of the balancing exhibit, with the distances and weights clearly marked so that her students can experiment with different weight-distance combinations. She even introduces the idea of a "mystery weight" that students must "solve for," using the other weights in the balanced configuration. Through the process, the students engage in rich conversations about equations, variables, and multiplicative relationships.

Photo courtesy of Oregon Museum of Science and Industry.

Figure 1
Mobile sculpture exhibit highlighting the multiplicative relationship among weight, distance, and force on each side of the fulcrum.

[1] However, note these important critiques about equity and diversity in the maker movement (Tan et al., 2018; Vossoughi et al., 2016).

Now imagine another scenario in which a middle school youth visits a maker space at her local science center. Inspired by sculptures she has seen and her own passion as an artist, she decides to create a balancing sculpture for the local community garden. However, she has trouble arranging her sculptural pieces so they balance correctly. With museum staff help, she discovers the relationship among weight, distance, and force that determines balance. Based on this research, she knows that she needs to hang the lighter sculptural piece about twice as far from the fulcrum as the heavier one. She then adjusts the arrangement until she achieves an overall balance that matches her artistic vision.

Both these examples depict rich math learning—one beginning with a core math concept and the other arising naturally as part of the making experience. Furthermore, both examples show the power of integrating math into hands-on, maker-related experiences. While neither of these approaches is necessarily better than the other, we are particularly interested in opportunities in which the mathematics arises naturally in service of goals set by the individual learner. These types of experiences can not only create a new perception of mathematics but also connect with a broader group of children and adults—highlighting their existing abilities as mathematical thinkers and sparking a renewed interest in math.

Our Own Maker Journey

There are few models of this authentic integration in the context of museum-based experiences. So, what might authentic integration look like? To explore this question, we partnered with the New York Hall of Science (NYSCI) and the Children's Museum of Pittsburgh (CMP) to test ways of enhancing mathematical thinking and learning opportunities in museum-based making activities for families. From 2018 to 2021, we worked collaboratively with partners to refine our vision for authentic integration, identify promising making activities, design and test these activities using a variety of strategies, and synthesize lessons learned.

Our experiences with these activities led us to identify four potential design strategies for highlighting and enhancing their math potential, outlined in the adjacent box. Next, we describe how our work with two of these activities led to our articulation of these strategies.

- Curate materials to highlight salient mathematical relationships
- Tailor design choices so that mathematical issues are more likely to emerge
- Highlight mathematical quantities that are consequential to the making
- Incorporate materials and cues that visitors may see as math related

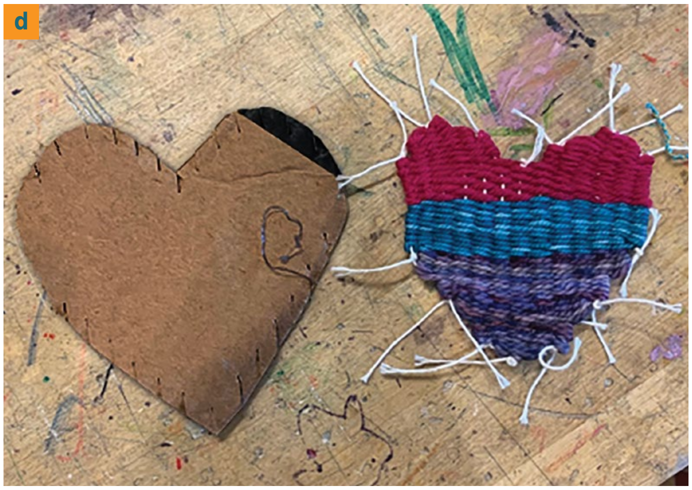
Weaving at the Children's Museum of Pittsburgh

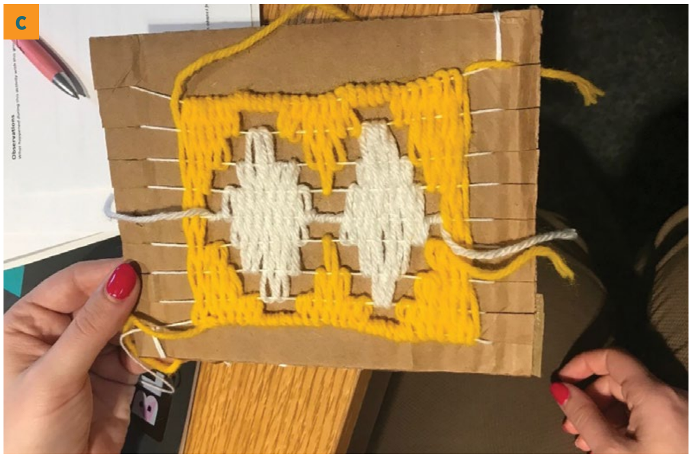
CMP's MAKESHOP®, which caters to young children and their families, always features a full-sized loom with an in-process community fabric project. In addition to using the large loom, visitors can create their own looms by making a series of small cuts in parallel sides of a piece of cardboard and wrapping yarn around it to create a warp. They then start weaving, using the familiar over-under-over-under process (**Figure 2a**). Even in this simple activity, we saw children and families engage with patterns (alternating over/under). But how could we extend the mathematical thinking in this making experience for visitors?

The MAKESHOP at CMP is staffed by "teaching artists," who are both educators and artists in their own right. Experienced weavers among the teaching artists noted two opportunities for mathematical reasoning in the process of weaving. The first recognized the reciprocal relationship between yarn thickness and the number of rows it takes to make a particular length of fabric. Thicker yarn makes weaving "go faster," since it takes fewer rows to fill a space (**Figure 2b**). The second mathematical insight focused on creating geometrical shapes in a woven piece. Making a pattern like the one shown in **Figure 2c**, for example, requires making a series of increasing then decreasing rows of white and keeping track of how long each yellow row should be.

Photos courtesy of Children's Museum of Pittsburgh.

Figure 2.
(a) Weaving with a cardboard loom at CMP.
(b) The thicker the yarn, the fewer rows needed to fill a space.
(c) This diamond pattern requires a series of increasing then decreasing rows.
(d) Non-rectangular looms invite careful mathematical planning.





Once we recognized this potential, we still had to decide how to increase the likelihood that visitors would encounter these mathematical aspects of weaving in a compelling and authentically integrated way. To address the idea of yarn thickness, we made yarns of very different thicknesses available, so it would become obvious how those thicknesses affected the length of the resulting piece.

To introduce the mathematical complexity that arises when weaving a design that includes non-rectangular shapes, we made sure that there were examples of woven pieces with diagonal lines and curves visible to visitors. However, a more successful mathematical enhancement came from one of our museum partners: pre-made, non-rectangular looms. These looms require careful mathematical planning because each row may need a different number of over-under pairs than the previous one. A heart-shaped loom was particularly popular with visitors, as seen in **Figure 2d**.

Figure 3 | Mannequin dolls for the fashion design activity at NYSCI

Making these changes to the weaving activity at CMP helped us identify two promising design strategies for authentically integrating math and making:

- *Curate materials to highlight salient mathematical relationships (e.g., yarn width)*
- *Tailor design choices so that mathematical issues are more likely to emerge (e.g., non-rectangular looms)*

Fashion Design at the New York Hall of Science

Our colleagues at NYSCI were passionate about fashion design, since it was an activity they enjoyed themselves and one that attracted a wide variety of visitors, including both girls and boys (**Figure 3**). Although it seemed clear that sewing involves mathematics, we wanted to get beyond the obvious connection with measurement. The idea of scaling—working from a pattern that might not be the right size—seemed worth exploring. To limit the amount of material visitors would use, we decided to provide medium-sized dolls for visitors to dress. We hypothesized that the presence of the patterns would inspire visitors to consider using them for the dolls' clothing while also signaling that there might be math involved in the process.

Unfortunately, the COVID-19 pandemic temporarily closed the museum just as this activity was being readied for the floor. However, the NYSCI team was able to continue iterating on the idea of clothing design and mathematics in partnership with its NYSCI Neighbors program, which focuses on serving the museum's highly diverse neighborhood in Queens. The *Math in the Making* project partnered with outreach staff to design a family mask-making workshop conducted over videoconference (**Figure 4**). Participating families received kits containing both practical materials for making masks, such as a tape measure and tape for fastening fabric, as well as materials for individualizing and decorating the masks, such as sequins. Families used scrap fabric they had at home, such as old T-shirts, to make the masks. The workshop focused on making child-sized masks, since most of the adults already had masks and well-fitting masks for children were hard to find at the time.

Families appeared to be highly engaged in the workshop, and many seemed to draw from their prior experience sewing and making clothes. Adults also seemed more aware that "math" was involved compared to other clothing design experiences facilitated by the museum. We observed families engaging in the mathematics inherent to the design process in a variety of ways—both through talk and gesture. Their math conversations seemed particularly motivated by the process of measuring specific dimensions of the face with the tape measure to ensure the mask would fit snugly, which made precise measurement consequential (**Figure 5**). These observations, and the team's iterative testing of both the fashion design and mask-making activities, highlighted two additional design principles for authentically integrating math and making and helping visitors become more aware of their own mathematical reasoning:

Figure 4 | A child explores how a mask fits her mother in a virtual mask-making workshop.

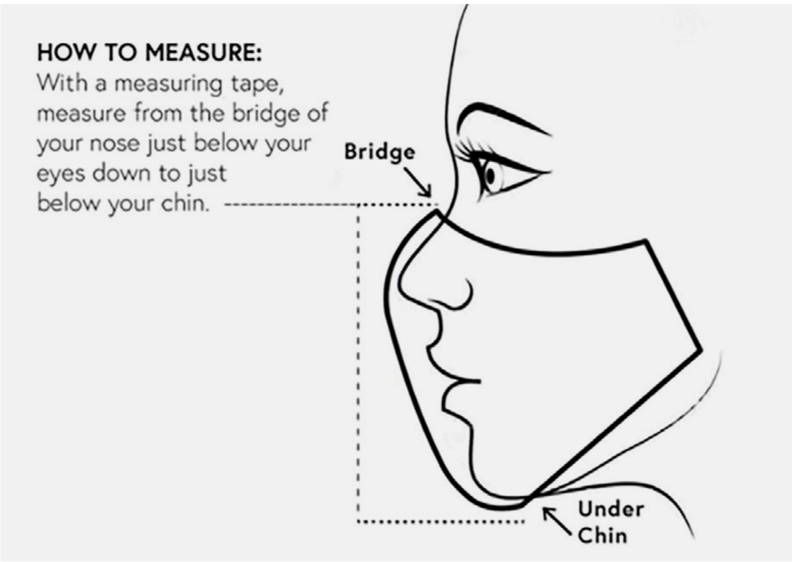


Figure 5 | Measuring specific dimensions of the face is critical to ensure the mask fits snugly.

- *Highlight mathematical quantities that are consequential to the making (e.g., dimensions of face for fitting mask)*
- *Incorporate materials and cues that visitors may see as math-related (e.g., clothing patterns, measuring tape)*

Conclusion

These stories represent just the beginning of our exploration into authentically integrating mathematics into making experiences—and using these experiences as an opportunity to help more children and adults see themselves as mathematical thinkers. We plan to use the design principles that emerged from our work as a starting point for additional research and the development of new programs and activities. Through this process, we hope to contribute to a more expansive vision of "doing mathematics" that resonates for all children and adults.

Additional Resources

Find out more about the *Math in the Making* initiative on the project website: **www.terc.edu/mathinthemaking**.

Acknowledgements

This work was conducted in close collaboration with our project partners and advisors, including Dorothy Bennett, Satbir Multani, Chip Lindsey, Rebecca Grabman, Alison Bank, Marta Civil, Peter Wardrip, and Debra Smith. *The Math in the Making* initiative was funded by the National Science Foundation under Grant No. 1514726 and 1811395. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Authors

Andee Rubin is a Senior Scientist at TERC with a background in math and computer science. She is committed to engaging people in the power of mathematics, especially data science, at all ages, both in and out of school.

Scott Pattison, Ph.D., is a Research Scientist at TERC. He partners with communities to study and support STEM education, learning, and interest development in free-choice and out-of-school environments, including museums, community-based programs, and everyday settings.

References

Calabrese Barton, A., Tan, E., & Greenberg, D. (2017). The makerspace movement: Sites of possibilities for equitable opportunities to engage underrepresented youth in STEM. *Teachers College Record, 119*(6), 1–44.

Cohen, R., & Kelly, A. M. (2020). Mathematics as a factor in community college STEM performance, persistence, and degree attainment. *Journal of Research in Science Teaching, 57*(2), 279–307. https://doi.org/10.1002/tea.21594

Denner, J., Valdes, O., Dickson, D. J., & Laursen, B. (2019). Math interest and self-concept among latino/a students: Reciprocal influences across the transition to middle school. *Journal of Adolescence, 75*, 22–36. https://doi.org/10.1016/j.adolescence.2019.06.015

Dika, S. L., & D'Amico, M. M. (2016). Early experiences and integration in the persistence of first-generation college students in STEM and non-STEM majors. *Journal of Research in Science Teaching, 53*(3), 368–383. https://doi.org/10.1002/tea.21301

Ganley, C. M., & Lubienski, S. T. (2016). Mathematics confidence, interest, and performance: Examining gender patterns and reciprocal relations. *Learning and Individual Differences, 47,* 182–193. https://doi.org/10.1016/j.lindif.2016.01.002

Gutiérrez, R. (2018). The need to rehumanize mathematics. In I. Goffney, R. Gutiérrez, & M. Boston (Eds.), *Rehumanizing mathematics for black, indigenous, and latinx students* (pp. 1–10). National Council of Teachers of Mathematics.

Jiang, S., Simpkins, S. D., & Eccles, J. S. (2020). Individuals' math and science motivation and their subsequent STEM choices and achievement in high school and college: A longitudinal study of gender and college generation status differences. *Developmental Psychology, 56*(11), 2137–2151. https://doi.org/10.1037/dev0001110

Martin, L. (2015). The promise of the maker movement for education. *Journal of Pre-College Engineering Education Research (J-PEER), 5*(1), 30–39. https://doi.org/10.7771/2157-9288.1099

National Council of Supervisors of Mathematics & National Council of Teachers of Mathematics. (2018). *Building STEM education on a sound mathematical foundation.* https://www.nctm.org/Standards-and-Positions/Position-Statements/Building-STEM-Education-on-a-Sound-Mathematical-Foundation/

NCTM Research Committee. (2018). Asset-based approaches to equitable mathematics education research and practice. *Journal for Research in Mathematics Education, 49*(4), 373–389. https://doi.org/10.5951/jresematheduc.49.4.0373

Pattison, S. A., Rubin, A., & Wright, T. (2017). *Mathematics in informal learning environments: A summary of the literature (updated).* http://www.informalscience.org/mathematics-informal-learning-environments-summary-literature

Tan, E., Calabrese Barton, A., & Schenkel, K. (2018). Methods and strategies: Equity and the maker movement. *Science and Children, 55*(07). https://doi.org/10.2505/4/sc18_055_07_76

Vossoughi, S., & Bevan, B. (2014). Making and tinkering: A review of the literature. *National Research Council Committee on Out of School Time STEM. Washington, DC: National Research Council*, 1–55.

Vossoughi, S., Hooper, P. K., & Escudé, M. (2016). Making through the lens of culture and power: Toward transformative visions for educational equity. *Harvard Educational Review, 86*(2), 206–232. https://doi.org/10.17763/0017-8055.86.2.206

Bringing *Math Talk* Home

By Anya Carbonell

Anya Carbonell is a Junior at Boston University majoring in international studies. As a TERC Scholar in the 2019-2020 school year, she worked on TERC's Aprendiendo *project, coordinating with Spanish-speaking families in the Boston area to expand and support mathematics education for Pre-K students.*

During my sophomore year at Boston University, I supported the project *Aprendiendo de familias: Learning Math Talk with Pre-K Spanish Speaking Families*, funded by the STEM Education Evaluation Center at TERC. The *Aprendiendo* project addresses the digital divide between parents and their young children by creating short, engaging videos modeling mathematic activities and sending them to families through a free mobile app. The project's goal is to engage Spanish-speaking parents and their young children in Math Talk through short videos and interactive mobile messages. This eye-opening experience showed me just how important it is to have parents involved in their children's learning, especially in math.

What is Math Talk?

Math Talk involves discussing introductory mathematical concepts like shapes, sizes, sequencing, and spatial relationships through daily activities such as organizing laundry and grocery shopping.

Pre-COVID, I spent time with project leaders Sabrina De Los Santos and Audrey Martínez-Gudapakkam preparing for the pilot of the project. We focused on reaching Spanish-speaking families with young children under the age of five, who didn't speak English and had limited literacy in their own language. Initially I considered the challenges of how this type of family — one closely resembling my own — would be able to participate in a research study like this one. My parents are essential workers as well as working class, leaving them little time to do any activities outside of their jobs. Both of my parents are mainly Spanish speakers, although my mother knows how to speak English. It was very difficult for me to imagine how parents who work long hours most of the week, like mine, would be able to participate in a project that required extra work outside of an already stressful and time-consuming workday. Nevertheless, I worked with the expectation that parents would regularly engage in math activities with their children, show up to interviews, and actively participate in the project.

Unforeseen Challenges

The pandemic made piloting our intervention strategies very challenging since our original plans involved meeting parents in person to help them overcome technology barriers. The families we targeted were struggling with financial burdens

as well as mental and emotional wellbeing. In order to provide adequate support, we had to be much more involved in helping them find resources to weather the difficulties the pandemic created. With the added layer of language and literacy barriers, we searched for viable technology options for families to use, and we ultimately relied primarily on WhatsApp™ for communications because it was a platform they were already using. In addition, we made ourselves available to meet with parents outside the traditional nine-to-five working hours.

Looking back, I realize that even without the pandemic, scheduling would have been a challenge because families would still have the same jobs that required them to work long hours. This worldwide crisis exacerbated these since it created even more hardships for socioeconomically disadvantaged families. For example, one of the parents in our pilot group worked odd shifts at a hospital as an essential worker and is the primary caretaker for her children as well as her niece, so she wasn't always available to work with

TERC Scholars Program

On site for up to 10 hours per week, each TERC Scholar becomes an active member of a project team and works under the supervision of the project's leaders to help advance project goals and gain STEM education knowledge. Scholars engage in authentic research activities, such as classroom data collection, literature syntheses, instrument testing, data coding and analysis, and case study development.

TERC Scholars come from a variety of backgrounds and majors. Each scholar is assigned a mentor who assists them in navigating a professional workplace and guides them toward professional development opportunities.

For more info, visit **https://www.terc.edu/work-with-us/terc-scholars-intership-program/**

us. Although we tried to schedule meetings far in advance, sometimes she needed to cancel at the last minute because a work or family issue came up. Despite the obstacles she faced, she tried her best to remain engaged in our project. Taking into consideration how overwhelming it could be to juggle so many things at once, we learned to modify our approach and be more accommodating. Our revised strategy included using different communication methods such as voice messages instead of text and limiting how frequently we contacted her.

Working at a Distance Provides Insights

During the pilot, stay-at-home orders forced me to go back home from BU. I spent the remainder of my spring semester with my family in New York, but this served as an advantage in disguise. My own parents became incredibly helpful in testing the forms we sent out to the parents participating in our project. I reviewed the consent form and interview questions with my parents, having them pinpoint where the wording might get confusing and burdensome for parents, and using their feedback to rephrase the forms in ways that were easier for Spanish-speakers from different cultures to read and understand.

"I've definitely grown by asking [the questions in the activities] to make sure the kids are getting the concepts. The questions showed me that 'good' math questions can be about thinking, rather than about finding the answer."

—ELR FACILITATOR ON CHANGES IN HER OWN LEARNING

I also realized how far-removed educational research can be from the realities of the everyday life of working-class families. When conducting a study, participants are expected to show up on time, adhere to the rules and regulations the researchers create, and conform to the ideas of what a researcher deems a proper fit to the research study. Research with strict timetables and deadlines sometimes do not fully consider those who cannot afford to work by that same schedule. Because of these limitations, people who could benefit the most from projects like ours might not be able to receive the support they need to participate in research. Working on this project during the pandemic was stressful, but also taught me many lessons about meeting research participants where they are.

Anya with her mom (right), Monica Mejia Rodriguez.

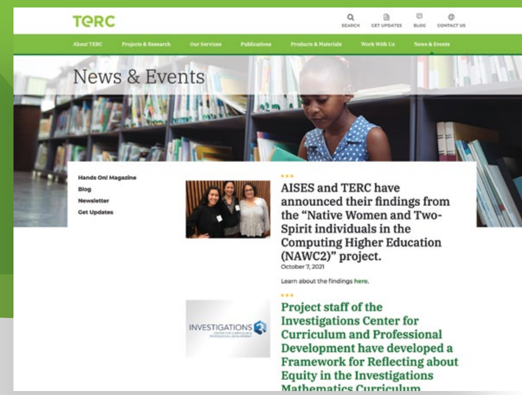
Despite being an international studies major, my time at TERC has helped me realize my interest in education-related research. I first heard about TERC and the TERC Scholars Program (TSP) through the College Access and Student Success Office at BU. Being a first generation and low-income college student, I was encouraged to apply while still being undeclared in my major, and the program has greatly influenced how I look at the world and approach real world problems. TSP was the first time I was exposed to any kind of research work, and because of the mentorship I received, I began to seriously consider a career in STEM research despite not majoring in anything STEM related. For a research project to work well and address the concerns of diverse groups, people from different backgrounds and skill sets are needed beyond having an academic background in STEM. However, the interdisciplinary angle of research is rarely discussed with students when they are asked about their future career interests. I hope that with more encouragement, more students with different educational backgrounds can participate in research projects to make them more meaningful and effective.

Acknowledgements

Audrey Martinez-Gudapakkam, Judy Storeygard, and Sabrina De Los Santos have all taught me so much during this project and have all helped me in every step of writing this article, offering invaluable knowledge and support. Thanks to my mother for the additional insight on this project. This article is based on the pilot process of the *Aprendiendo* project, internally funded by TERC. Thanks to Stephen Alkins, TSP director, for his continuous encouragement and support throughout my time at TERC.

To learn more about this project go to:
https://www.terc.edu/projects/aprendiendo/

What's New at TERC.edu?



Finding the information you're interested in has never been easier. Looking for the latest news? Click on "News and Events" in the top menu.

terc.edu/news-events

Join our new research study for teachers grades 3-8!

INFACT

https://bit.ly/3kkR1JV

INFACT is a teaching and learning program for students in grades 3-8 involving a variety of on- and off-line computational thinking (CT) learning and teaching materials. Materials and supports benefit all learners but also leverage the strengths and support the challenges of neurodiverse learners (e.g., ADHD, autism, or dyslexia).

Teachers will gain access to the INFACT portal where they can pick and choose activities to explore foundations and applications of CT, a problem-solving process.

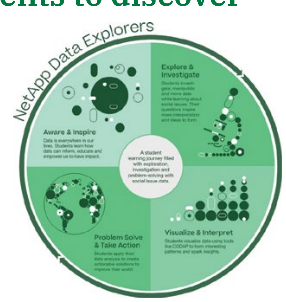
The INFACT study will take place February-April 2022.

Join INFACT and get access to computational thinking, coding, and robotics materials. Plus stipend $$$

Find out more at https://bit.ly/3kkR1JV

TERC is proud to be partnering with NetApp to empower students to discover and develop critical data skills!

https://ntap.com/3H3wHX3



Learn more about the 12-week curriculum titled Data Explorers, developed by TERC through funding and partnership with NetApp and in collaboration with Concord Consortium and the India STEM Foundation. The NetApp Data Explorers program focuses on data awareness using data tools and games and complex datasets and visualizations with the goal of helping underrepresented students become more fluent with data.

Investigations Center for Curriculum and Professional Development created a framework for reflecting about equity in the *Investigations* Mathematics Curriculum

investigations.terc.edu/equity

This working draft is available for school-based educators who might also find it useful as a tool for reflecting on issues of equity, identity, and agency in mathematics learning and teaching. The framework and other evolving resources can be found at investigations.terc.edu/equity.

INVESTIGATIONS 3
CENTER FOR CURRICULUM & PROFESSIONAL DEVELOPMENT

A Moving Dune, a Stunning View: Visitors' Recollections of a Ranger-Led Hike at Indiana Dunes National Park

Brian E. Forist, Martha Merson, Louise C. Allen, Nickolay I. Hristov, Forist BE, Merson M, Allen LC and Hristov NI (2021) doi: 10.3389/feduc.2021.675672

https://bit.ly/3v4Luv2

Located 50 miles from Chicago, at Indiana Dunes National Park, thousands interact with rangers annually, many taking part in ranger-led hikes. The study focused on visitor recollections of a ranger-led hike that provided opportunities to learn about landscape change, recent events, and associated scientific findings.

Read the latest TERC Blog posts

blog.terc.edu

Get a first look at newly-funded innovative research projects, dive deep into STEM education topics, gain insights into our research—all this and more on TERC's blog!

"I think around the box"

By Christina B. Silva, Nuria Jaumot-Pascual, Maria Ong, Kathy DeerInWater

A look into the journey of a CS undergraduate from an underrepresented group in STEM programs, Natives—and even more rare, two-spirit and how his identity helped him change minds and create opportunities.

Engineering for Equity

By Scott Pattison and Smirla Ramos-Montañez

For decades, scholars across a variety of fields have been calling for a re-examination of the ways that we address inequities in STEM education. Challenges and events over the last several years are starting to give these ideas about equity the attention they deserve.

Thanks to funding and support from TERC, over the last year Scott Pattison and Smirla Ramos-Montañez have taken a few hours each week to reflect on assumptions, learn from others, and explore new ways that their research could both uncover and help dismantle inequities and racism in the STEM education system.

Posts reflect on:

- evolving ideas about collaborating with families,
- asset-based approaches to STEM education,
- rethinking how we define engineering, and
- themes that have emerged throughout the process.

Zoombinis

www.FableVisionGames.com

TERC is thrilled to bring its beloved Zoombinis game to the world of teachers. With our partners, FableVision, we now have a complete turnkey program for the classroom with the facility for teachers to track progress, assess student understanding, and improve students' Computational Thinking skills.

Sign up for an account at www.FableVisionGames.com

Storytelling Math Series

https://bit.ly/3kU33HZ

New titles are now available in Spanish from Charlesbridge Publishing! Under the direction of Marlene Kliman, these picture books meld story, racial diversity, and math and are written by authors of color. Each book celebrates children using math in their daily adventures as they play, build, and discover the world around them.

- **¿Qué llenarà la canasta?** /What Will Fit?
- **¡Círculo! ¡Esfera!** / Circle! Sphere!
- **El último malvavisco** / The Last Marshmallow
- **¡Hasta las rodillas!** / Up to My Knees

Plus two new books:

- **Look, Grandma! Ni, Elisi!**
- **Usha and the Big Digger**

Congratulations Storytelling Math

Lia and Luís: Who Has More? by Ana Crespo, won the 2021 International Latino Book Award Silver Medal for Best Educational Children's Picture Book — English or Bilingual.

TERC | Because math and science build futures

2067 Massachusetts Avenue • Cambridge, Massachusetts 02140

terc.edu @TERCtweets TERCed

Nonprofit Org.
U.S. Postage
PAID
Permit No. 402
Brockton, MA

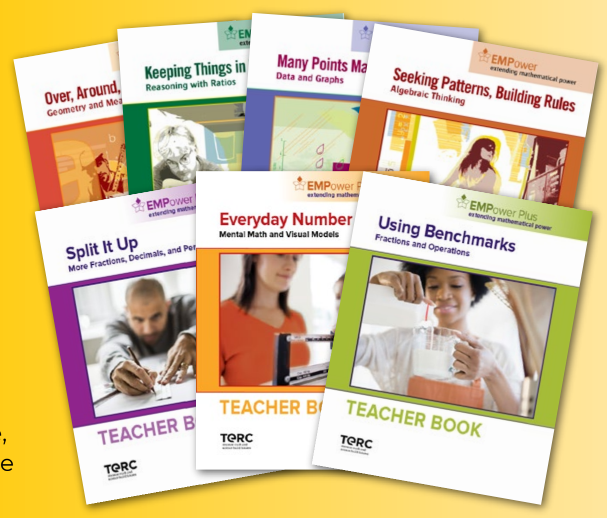
Teach math conceptually! EMPower

TERC's EMPower™ is an innovative series that provides adults and adolescents with the conceptual understanding necessary to succeed as they seek a high school credential, college degree, or advanced job training.

EMPower helps educators and students:

- Explore ideas through open-ended investigations
- Engage in activities that relate to their lives
- Develop connections within math topics
- Collaborate and share ideas verbally and in writing
- Discover multiple problem-solving methods
- See relationships between situations, graphs, tables, and equations

With EMPower, algebraic, statistical, and geometrical ideas are developed as students learn to apply foundational number sense, estimation, and problem-solving skills to real-world situations. The seven-title series teaches and reinforces the **College and Career Readiness Standards for Adult Education**.



TERC
Lesson samples, info, & PD support
https://www.terc.edu/empower

WALCH
Titles available from Walch Education
https://www.walch.com/terc-empower

Get *Hands On!* delivered to your inbox! Email communications@terc.edu to update your preferences.