HANDS ON!

A magazine for mathematics
and science educators

TERC

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03

Embodied Learning through Dance and Physics

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Letter from the President

In the Fall 2019 issue of *Hands On!* we share three research projects which focus on enhancing the STEM learning experience of individuals from underserved communities. Although the learning takes place in different settings, with different aged learners, they each explore how STEM concepts can be taught and learned via multiple mechanisms including early childhood books, hands-on engineering activity kits, and the art of dance.

In our feature story, *Embodied Learning through Dance and Physics*, African American high school girls learn physics concepts via dance movement instruction and expression. Kinesthetic learning, a person's ability to process information through hand and body movement, control, and expression, is a learning style more accepted in early learning. Here, kinesthetic learning is explored while teaching high school girls physics concepts such as balance, gravity, and angular momentum in dance class. Dance and body movements act as a sense-making tool for learning physics. Just imagine where this exciting research could lead.

In *Storytelling Math*, readers will get a glimpse into an innovative partnership. The shared goal is to enrich the selection of books available to young children to include stories that are based on families of color and incorporate mathematical concepts such as understanding patterns, spatial relationships, and everyday vocabulary. Working with children's book authors and conducting workshops and webinars, the team solicited and selected among 450 story submissions. In partnership with Charlesbridge Publishing, these chosen manuscripts will be available to families beginning in the fall of 2020.

One typically envisions engineering thinking and problem-solving skills as relevant for school aged children. In *Head Start on Engineering*, you will read about a collaboration with the Mount Hood Community College (MHCC) Head Start program, the University of Notre Dame and the Oregon Museum of Science and Industry. The multi-component, bilingual (Spanish and English) program is designed to engage low-income children ages 3 to 5 and their families in the engineering process. The four kits comprise activities that families can engage in at home and include a storybook, simple materials, a parent facilitation guide, and online video demonstrations. Learn about two new projects being launched to extend the reach of this program with new partners as well as a study on the impact on families over time.

Enjoy the issue.

Laurie

Laurie Brennan, *President*

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Embodied Learning through Dance and Physics

Scholars across disciplines recognize the power of bodily experiences in shaping cognition. While a number of scholars suggest that dance represents an important type of embodied cognition, the notion of dance as a site for learning is underexplored (Sucato, 2009). Our team received a two-year Exploratory Pathways Project grant from the National Science Foundation's Advancing Informal STEM Learning program for a project entitled *Embodied Physics: STEM Learning for Under-Represented Youth*. *Embodied Physics* constructed a physics course for high school students from two Boston-based dance schools. These young dancers were able to engage in ways of learning that recognized their embodied knowledge of physics, rooted in their experiences as dancers, and that celebrated the cultural knowledge they had developed in their community-based dance schools (see sidebar on page 4).

By Folashade Cromwell Solomon, Tracey Wright, Mariah Steele, and Dionne Champion

Students in Phase 3 balance equal and opposite forces.

Building Science Identities

Informal learning contexts provide one avenue for broadening participation in science for underrepresented students. We developed the Learning Lab as part of an effort to explore how such youth can develop not just science knowledge but scientific identities. We hypothesized that embodied learning would provide rich opportunities to learn key ideas in physics and to strengthen their confidence in their ability to become scientists.

Our process began with observing high school dancers learning in environments—their dance studios—where they were already embedded in and engaged with their home communities. The Lab itself was situated in a central location in the students' neighborhood, and the course supported discussion of physics concepts drawn from their lived and embodied experiences, to help them identify themselves as people who practice and are engaged in scientific inquiry.

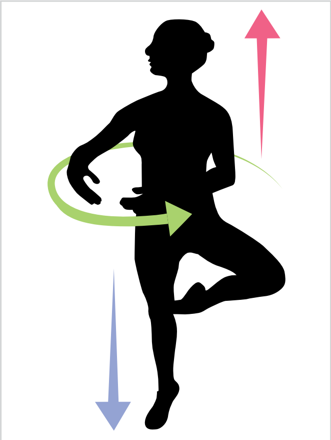
The *Embodied Physics* project was comprised of three phases. In Phase 1, we partnered with OrigiNation in Jamaica Plain, MA and Roxbury Center for the Performing Arts in Dorchester, MA. These urban community-based dance studios primarily serve African American dancers and have a history of excellence in dance education and of significant contributions to their wider communities. Next, during Phase 2, we worked with dance students from Boston Conservatory (BOCO) and STEM students from MIT to connect dance experiences to specific physics "tasks," to help us develop course material. During Phase 3, we drew on what we learned from Phases 1 and 2 to create the *Embodied Physics* Learning Lab, which allowed 15 high school girls from the two community-based dance studios to come together to explore physics concepts by using their bodies as resources.

Embodied understanding, or kinesthetic learning, is one of eight types of learning styles defined in Howard Gardner's Theory of Multiple Intelligences (Gardner, 2011). Kinesthetic learning style refers to a person's ability to process information through hand and body movement, control, and expression. Kinesthetic intelligence entails using one's whole body or parts of the body to solve problems. While kinesthetic learning is at times acceptable for elementary students, in middle and high school it is seen as improper and less academic. Thus the potential for using the body as a resource for learning for all students is largely undervalued and underexplored.

Our project, *Embodied Physics,* saw the potential to use dancers' enacted knowledge of physics as a way to locate physics knowing in an everyday context. Through the project, participants were able to discover the physics within something they cared deeply about, dance.

Participants in the *Embodied Physics* Learning Lab (Phase 3) met for eight, three-hour sessions at a centrally-located dance studio within a Boston public school. The students engaged in a series of activities (developed from our learning process in Phases 1 and 2) to become aware of how much they already knew about physics kinesthetically and of how they could articulate that knowledge.

Kinesthetic Understanding of Physics through Dance



During our Phase 1 observations at OrigiNation and Roxbury Center, we noticed that teachers' use of imagery and metaphorical language during classes and rehearsals supported students in developing a kinesthetic sense of physics concepts.

> *During a ballet class, one teacher commented, "Remember to drill your foot into the floor in order to pirouette," and then demonstrated. The dance studio director added, "Every time you do a pirouette.... You're like that pole. You don't bend."*

In the above quotation, the physics concept of balance is addressed in relation to a pirouette. The teacher used imagery ("drill") as well as demonstration to explain the idea of equal and opposite forces. She pointed out that it is important to push down, in order to rise up to turn. This imagery provides students with a kinesthetic direction to work with the force of gravity. The dance studio director used a metaphor that alludes to physics when she added that students should be "like that pole." By inviting students to hold themselves stiff and straight like a pole while turning, she was teaching them to resist angular momentum (the turning force) in order to stay upright.

In this example, we see how students enacted a sense of the science and gained a kinesthetic knowledge of the physics through their bodily experiences of dancing. The teachers' use of embodied imagining — through imagery and metaphor — is a crucial concept in both physics and dance education, suggesting yet another way that dance and the body can contribute to STEM learning.

Phase 2: Students drew arrows onto photos of their dance to highlight forces at play

Phase 3: Students developed contemporary style choreography to represent the characteristics of Hydrogen and Oxygen and how these elements come together to form water.

Dance as a Sense-Making Tool

The pirouette example from Phase 1, mentioned previously, inspired the design of a Jumping Activity in Phase 3. First, students participated in a conversation about forces, gravity, and rotation. Then, they worked in pairs to lift each other up as high as they could and make 90 degree turns to the right. Students engaged in the activity enthusiastically, smiling, laughing, and collaborating with their partner in order to articulate what they had to do to succeed at this task. The teacher then asked the students to interpret their experience through a physics lens.

Teacher: *To jump up, what did you do?*

Student: *You push off the ground.*

Teacher: *What does the ground do?*

Student: *It pushes you back. Newton's 3rd law. Like when you're walking.*

Teacher: *With turning, what did you do differently?*

Student: *Exert a force to the side.*

Teacher: *So you are twisting. A directional force.... How about when you are flying up? What forces are acting on you?*

Student: *Gravity. Maybe your partner.*

In this example, we see students using their bodies to make sense of the prior conversation about physics concepts. By immersing themselves in the phenomena of jumping and turning, and by discussing their actions using both everyday and physics language, they were using dance as a sense-making tool for learning physics. The teacher used the language of physics to question and respond to students, as well as to support students in articulating what they already know and feel in their bodies. The body became a resource for making sense of physics.

On the last day of the Learning Lab, we held an "Embodied Physics Exposition" for an audience of teachers, parents, colleagues, and friends. This final performance gave students a chance to demonstrate their knowledge to others by performing dances they had choreographed about a physics topic of their choice.

Embodiment to Enhance STEM Interest

Embodied Physics has found that our students' prior dance experience fosters an intuitive, kinesthetic understanding of physics through imagery and metaphorical language, and that creating space for students to bring what they already know to the table, allows them to use dance as another tool for making sense of scientific concepts and for communicating their knowledge. In addition, this project is continuing to explore the use of the body in other ways, including how the body can "Re-Present" the physics (Champion, 2018; Hall, 1996) and how choreographic structures, such as improvisational scores, theme and variation, and narratives can help students discover, deepen, and articulate their physics knowledge. Put together, these observations suggest important ways to enhance student engagement through embodiment and kinesthetic learning, which could be harnessed in other contexts to help students make sense of STEM content.

While this project focused on physics and on a group of dancers who are primarily African American youth, our methods and discoveries add to the toolkit of effective teaching practices for all STEM subjects and could impact the teaching of physics for much broader audiences in both formal and informal settings, including pre-high school students who will not be exposed to formal physics classes for many years, adults who may have been turned off to physics at an earlier age, and undergraduate STEM majors who are struggling with tricky concepts.

What might it look like to use the body as a tool for sense-making in your setting?

Students in Phase 2 deal with Newton's 2nd law (F=ma) using their own bodies of different masses.

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FOR MORE INFORMATION

Please contact Dr. Solomon (folashade_solomon@terc.edu) for more information or articles on this work.

AUTHORS

Principal Investigator Folashade Cromwell Solomon (Ed.D.), has over eighteen years education experience, first as an elementary teacher, then as a researcher and professional developer at TERC. Her central teaching and research focuses on learning, identity, and exploring the connections between the Arts and STEM with underrepresented youth. Dr. Solomon is also an Assistant Professor of Education at Framingham State University.

Tracey Wright, MEd, was an elementary teacher before becoming a researcher and developer at TERC for the past 25 years. Through her research and publications, she has contributed to the field of formal math education and informal science education with a focus on embodied learning.

Mariah Steele, a choreographer, educator, and interdisciplinary researcher, is currently the Artistic Director of Quicksilver Dance and a Lecturer in Dance at the University of Rochester.

Dionne Champion, PhD, is an educator, engineer, dancer, and learning scientist. Her research has focused on the design and ethnographic study of informal learning environments that blend STEM and creative embodied learning activities, particularly for children who have experienced feelings of marginalization in STEM. She is a Research Assistant Professor at the University of Florida.

THANKS

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Storytelling Math

Picture books as a vehicle for expanding views of math and who can do it

By Marlene Kliman

Think of a math picture book for ages 0–5. What comes to mind?

If you're like most adults, you think of books about counting or shapes. The books that come to mind are likely to feature animals or white main characters, rather than reflecting current U.S. demographics, in which young children of color predominate. These books may be better-suited to a math lesson than to a favorite bedtime read aloud, and chances are, they were written by white authors.

Why don't we tend to think of books that offer a wider range of math topics, feature main characters of color, appeal to a broad audience, and are written by authors of color? Because few such math picture books exist.

The STORYTELLING MATH project, based at TERC, Inc., is working to change the landscape of math picture books. With our partner Charlesbridge Publishing, we are producing a dozen English and Spanish books that:

- feature math topics that research shows to be important for young children but that make scant appearance in fiction picture books;
- center on authentic mathematical contexts that young children encounter in their daily lives;
- have main characters of color; and
- are designed to draw in families that may not intentionally be seeking out math—but will find it in our books, woven into emotionally resonant, engaging stories.

With these books, we aim to broaden popular conceptions of content, contexts, and characters in math picture books; and with our stellar authors and illustrators of color, we hope to expand views of who can create math picture books for young children.

Why combine math and picture books?

Infusing math into picture books offers an unparalleled opportunity to promote learning among young children in the years before they enter school. The benefits of reading to and with children are well known; when math and literacy are combined, children experience synergistic impacts in both domains, with growth in complexity of language, vocabulary, mathematical understandings, and enthusiasm for learning (Ginsburg et al., 2016; van den Heuvel-Panhuizen and Elia, 2012; Anderson et al., 2005). Opportunities for early math learning are essential: early math skills are one of the best predictors of overall academic success in the years to come (Morgan, 2016; Mongeau, 2013; Sonnenschine et al., 2012).

Why Extend Math Content and Contexts in Picture Books?

Although common views of appropriate math for children in the preschool years have long centered on counting and identifying shapes, a burgeoning research literature suggests the importance of a wider range of early math skills, including understanding of patterns, spatial relationships, and everyday math vocabulary (DREME, 2019; Erickson, 2019; Pruden et al., 2011; Purpura et al., 2016; Rittle-Johnson et al., 2016). Connecting math to developmentally-appropriate experiences also contributes to understanding: math stories about contrived situations in which children would rarely if ever use math in real life can serve to exacerbate conceptions that math has little practical utility (Sitabkhan et al, 2018). By contrast, math stories grounded in contexts in which children organically use math can foster a sense that math is relevant, helpful, and interesting.

Why is Racial Diversity in Children's Books So Important?

Books can be both mirrors and windows (Bronson, 2017; Lin, 2016). As mirrors, they should reflect our nation's racial diversity. Books that offer children of color positive portrayals of families like their own can promote self-esteem and healthy development (AACP, 2016; Pew Research Center, 2015). Positive math identity for young children of color is critical: despite decades of calls for change, pernicious "deficit" discourse appears in math education as early as preschool (TODOS and NCSM, 2016). As windows, books featuring children of color are vital for white children. Such books enable all readers to see children of color portrayed as fully realized characters.

Although librarians report that patrons of all backgrounds are eager for more diverse books, fewer than 25% of children's picture books published in 2018 include any characters of color; of those that do, many are thematic books about particular racial or cultural groups, festivals, or historical figures (CCBC, 2019; Mortensen, 2019; SLJ, 2019). Books that portray children of color doing everyday things—including mathematical thinking—are in short supply.

Some in the storybook world employ animal characters in attempt to avoid issues of race; this approach does nothing to attain parity between U.S. demographics and character representations in books. Since most human characters in children's books are white, using animal characters, rather than human characters of color, sustains the status quo.

Furthermore, recent research suggests that human characters in storybooks, and *not* anthropomorphized animal characters, are effective at promoting prosocial behaviors and patterns of thinking (Craig, 2017; Larsen et al., 2017). The possibility of a similar mechanism at work for math attitudes, confidence, and reasoning offers yet another reason for featuring people of color in math-infused storybooks.

The Dearth of Books that Meld a Rich Range of Math, Diversity, and Story

With growing awareness of the importance of early math and of the power of storybooks to promote math learning, lists of "best" mathematical storybooks for young children have proliferated. Prominent early childhood organizations and publications offer recommendations, and internet searches reveal myriad suggestions submitted by educators, librarians, and parents. Yet, very few titles on these lists reflect today's racially diverse families; instead, white children and animal characters predominate. For instance, a few years ago, *The Horn Book*, perhaps the preeminent periodical on children's literature in the U.S., recommended 14 math picture books for

In this board book for toddlers, Olivia looks for something the right size to fill her basket. "The beet is too small. It has room to roll around."

young children (Quinlan, 2015). Of the 12 that include human characters, only one has a main character who appears to be African-American or Latinx, none offers biracial or multiracial families, and just one was published after the year 2000.

Likewise, most such lists offer a narrow range of content (primarily counting and learning shape names), missing important opportunities to engage young children and their caregivers in the full breadth of enriching, relevant, and developmentally appropriate mathematics.

To gauge literary qualities and beyond-classroom appeal of books commonly found on "best" math picture book lists, we have begun asking children's book stakeholders, e.g., authors, editors, and book reviewers, to rate a sample of such books along a variety of dimensions. Our preliminary findings suggest that stakeholders believe that few of these books include the qualities—like emotional resonance, relatable characters, and a tension-filled narrative arc—that make for an outstanding fiction picture book.

Influencing the Influencers of the Children's Book World

To find out why so few books combine math, racial diversity, and the best qualities of children's literature, we look to the world of children's trade publishing. Publishers wield tremendous power as gatekeepers. On average, they accept *only about* .03% of submissions they receive (Underdown, 2010). Which stories do they choose? Children's publishing is a predominantly white and female field, and despite the best of intentions, biases about race and anxieties about math can prevail (Lu, 2019; Templeton, 2019). Some authors avoid traditional publishers by self-publishing or choosing another non-traditional route. Yet, aligning with traditional trade publishers confers substantial benefits. Publishers can provide professional editorial and design experience, promote books to a wide range of audiences, ensure that books appear in prominent displays in stores, and, through advertising and media, influence public opinion and tastes.

Our STORYTELLING MATH books will reap these benefits through our partnership with Charlesbridge, an independent trade publisher. To develop the STORYTELLING MATH books, Charlesbridge and TERC reached out to authors to solicit manuscripts in a variety of math areas that are under-represented in fiction picture books, but that recent research highlights as important for young children (including spatial relationships, reasoning quantities and informal measurements, and comparing patterns). We also offered free workshops and webinars to provide authors with more information on the math topics we sought: most author participants had never before considered that math for young children could consist of more than counting and shapes. We encouraged authors to write from the heart: to tell stories that mattered to them, and to connect with us for math support if needed.

"When TERC first approached us about STORYTELLING MATH, we were immediately interested," says Alyssa Mito Pusey, Executive Editor at Charlesbridge. "Charlesbridge has always been committed to diversity. The idea of publishing math books for young children of all backgrounds spoke to us. Here was a chance to publish books that could truly make a difference."

We received over 450 submissions. As we reviewed and selected among them, we carefully chose stories to reflect a balance of math topics, ethnicities, cultures, and story themes. Interestingly, none of the authors whose manuscripts we ultimately selected have a background in early math or math education; several professed anxiety about, or even, dislike of math. Yet, they were skilled at weaving engaging stories, and they typically brought an intuitive understanding of children's mathematical thinking—although they may not have recognized it until we talked through math ideas with them.

We are pleased that of the twelve manuscripts we selected, eleven of them are #OwnVoices stories by authors of color. The #OwnVoices movement highlights books by authors who share a marginalized identity with their protagonists: an African American author writing about an African American character, for instance. "#OwnVoices authors can write about their characters with unparalleled authenticity and nuance," says Pusey. "As an Asian American editor, I'm proud to be working on these stories. Young readers of color can see themselves reflected in these books in a way that I couldn't, growing up."

Since selecting the manuscripts, we have worked closely with Charlesbridge editors and designers to ensure that the books are well-written, beautifully illustrated, and mathematically sound. Later in the process, we'll collaborate with Charlesbridge's world-class sales and distribution partner, Penguin Random House Publishing Services, to reach as many readers as possible.

Will We Make a Difference? Stay Tuned

Our first books will be released in fall, 2020. We hope they make an impact on several levels: sparking mathematical thinking, learning, and conversation among readers; giving the public a broader vision of math picture books; and perhaps even prompting other publishers to follow the Charlesbridge lead, offering picture books that are mathematically rich as well as beautiful, lyrical, broadly appealing, racially diverse, and written by authors of color.

Visit TERC.edu to join our mailing list and be the first to know when the books will be available!

PHOTO CREDIT

Illustration © 2020 by Grace Lin from *Fall: What Will Fit?* Used with permission of the publisher.

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Heartfelt thanks to the Heising-Simons Foundation for their vision, their deep commitment to racial equity, and their enthusiastic and generous support; to Alyssa Mito Pusey and her colleagues at Charlesbridge for their collaborative spirit and for ensuring that these books are joyful, resonant, and beautiful as well as mathematical; and to Star Bright Books for the stellar math board books developed with Ellen Mayer and Ying-Hwa Hu as part of our pilot effort, also funded by the Heising-Simons Foundation.

AUTHOR

In over 25 years at TERC, Marlene Kliman has led national-scale research and development projects involving mathematics learning in public libraries, after-school programs, community-based child care settings, family homes, and other informal learning environments. Her projects have been funded by public and private agencies including the National Science Foundation, the Heising-Simons Foundation, and the IBM Work/Life Fund.

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TERC's New Look, Looks Forward

As TERC continues to grow, we want our brand to reflect what we believe in and why we exist. We're excited to share these brand updates and explain why we made them.

1970's

Technical Education Research Centers

1990's

TERC

2019

Because math and science build futures

You've probably noticed that TERC's website and materials have a new look. We've recently updated our logo, typeface, tagline, and imagery. We're still the same TERC you know and love, but with an updated brand that reflects our belief in the power of STEM education to move the world forward.

When we started in 1965, our name, Technical Education Research Centers, described our focus on technical and occupation education, primarily at the post-secondary level. These days our scope of work has expanded, and our name stands for more. Today we embrace education initiatives from across the STEM fields, serve learners in an array of settings, and believe more strongly than ever that math and science education builds futures. That is why we recently changed our legal name to our familiar acronym, TERC.

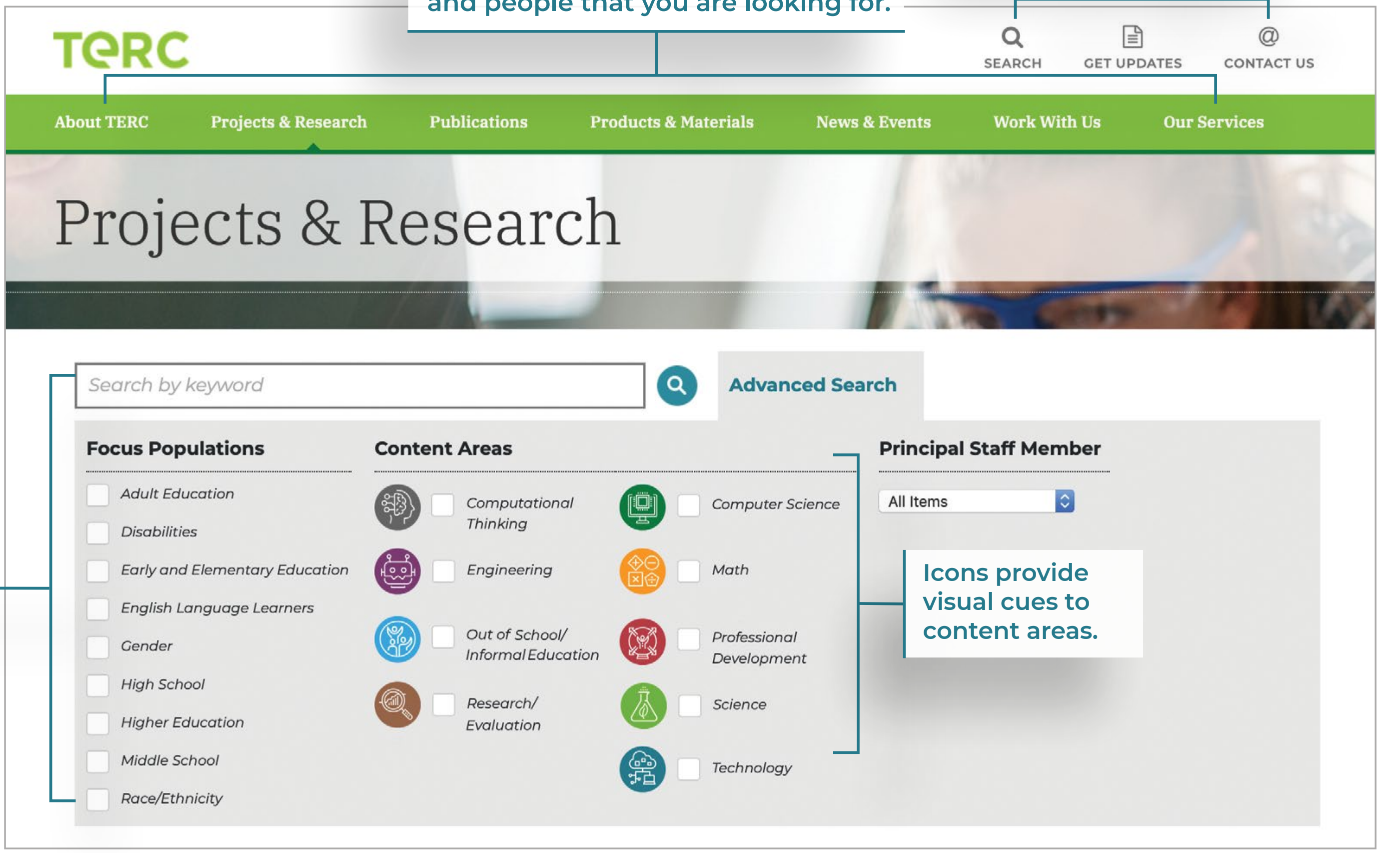
With this change comes new opportunities to share our powerful mission with stories, images, and new online tools. Throughout our history we have strived to be stewards of STEM education and advocates for teachers, learners, and innovators. With this brand redesign, we set out to encompass that passion and to showcase TERC's expertise in STEM education.

A robust search solution allows you to search the site by keywords, content areas, focus populations, and staff members.

We've also made a complete overhaul to our website, so it's easier for you to find the information you're most interested in. Here are a few highlights:

Quick links to site search, email sign up, and contact form.

Top level links to the projects, research, products, publications, and people that you are looking for.



Icons provide visual cues to content areas.

Dynamic profile pages cross-link to each staff members' projects, publications, research, and products, so you can connect with and get to know the people behind our ground-breaking work.

A simple-to-complete contact form enables you to stay in touch and customize the information we send you in the future.

Explore the site and tell us what you think! **contactus@terc.edu**

What's Up Next

We're working on an interactive timeline where you'll learn about TERC's history and how we've contributed to STEM education over the years. Follow us on Twitter and Facebook for updates and check back at terc.edu in January 2020!

@TERCtweets Facebook.com/terced Linkedin: TERC

Thank you to our entire community for your support and partnership over the years. We hope the new brand will inspire all of us to tackle big challenges, stand for equal access, and build futures through math and science education.

We use our new 'personified' logo on social media and conference materials as a more informal, accessible look.

FEATURE // PATTISON, RAMOS-MONTAÑEZ, SVAROVSKY SMITH, NUÑEZ, AND DOUGLASS

HEAD START ON **ENGINEERING**

SUPPORTING ENGINEERING INTEREST DEVELOPMENT IN EARLY CHILDHOOD FOR LOW-INCOME FAMILIES

In the United States, there are large and persistent disparities across communities in the available opportunities for children and their families to access quality STEM learning experiences and connect meaningfully with STEM throughout their lives—especially within the field of engineering.

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A family reads a storybook associated with the HSE nest-building engineering design challenge.

Parents get comfortable with the engineering design process at one of the HSE parent workshops.

Engineering thinking and problem-solving skills are now integral topics in STEM education and essential to success in work and life (Moore et al., 2014). Engaging preschool-age children and their families in this topic is a critical opportunity. Children begin building the foundations of engineering-related knowledge, skills, and interests before they enter school, thus supporting not only STEM engagement but also a variety of fundamental learning and development domains, such as problem-solving and mastery motivation (McClure et al., 2017). Unfortunately, children from underserved and under-resourced communities, especially Spanish- and English-speaking families from low-income backgrounds, remain underrepresented in engineering (National Science Board, 2018). These populations face a variety of barriers in pursuing engineering degrees and careers, including a lack of culturally and linguistically relevant learning resources and out-of-school enrichment opportunities (Takeuchi et al., 2019).

Since 2015, the *Head Start on Engineering* (HSE) initiative (https://hse.terc.edu) has worked to address these challenges by engaging staff and families in the Mt. Hood Community College (MHCC) Head Start program, based in Portland, Oregon. Conducted in partnership with MHCC Head Start, University of Notre Dame, and the Oregon Museum of Science and Industry (OMSI), HSE is a multi-component, bilingual (Spanish and English) program designed to engage low-income children ages 3 to 5 and their families in the engineering process. The overarching goal of HSE is to help families develop long-term interests in engineering and science so they will have the skills, knowledge, and confidence they need to be successful. Beyond school readiness, the program is about helping children and their families develop a passion for engineering and science that motivates them to engage with these topics throughout their lives—building what are often called long-term interest pathways. Unlike many other preschool engineering or science programs, HSE focuses on the family and home-based learning experiences first and then creates complementary classroom activities to support this learning.

Program Model

What does an early childhood engineering program look like when it supports engineering-related interest development for the whole family and integrates multiple experiences across contexts for parents and children? The backbone of HSE is a set of four bilingual family take-home engineering kits. Each kit centers on a hands-on engineering design challenge and includes the following:

- a bilingual storybook carefully selected to launch the activity and create a context for the engineering process;
- simple materials parents can easily reuse, replace, and supplement;
- a parent facilitation guide with instructions, facilitation tips, and extension ideas; and
- online videos demonstrating the take-home activities.

For example, the Fox and the Hen activity kit challenges parents and children to work together to build a tower of foam blocks that is over one foot high (https://vimeo.com/256122624). To set the context, the family reads a story about a group of hens looking for ways to protect their nests from a fox. After reading the storybook, families build a tower to protect the nest and then test their design by measuring it against a one-foot high cardboard image of a fox included in the kit.

These take-home kits are the anchors for the array of HSE program components integrated within the Head Start model, which also includes:

- a three-part parent workshop series;
- classroom activities designed to mirror the take-home kits;
- home visits by Head Start staff to check in with families; and
- a culminating science center field trip.

Across these experiences, the HSE program emphasizes the engineering design process, rather than engineering careers, as a topic and skill closely connected to family life and early childhood play. The parent workshops describe engineering as "designing and testing ideas to solve problems in work and life," and the engineering design process is introduced as an iterative cycle: ask, imagine, plan, create, improve (Cunningham, 2018). The word "engineering" is used throughout, but the focus is sparking and sustaining family interest in the engineering design process.

Underlying this program model is the fundamental belief that interest development and engagement with engineering (and other STEM topics) at this age involves not just the child but the whole family (Pattison, et al., 2016). In other words, parents and other significant adults change and learn in parallel with children and learning and development are supported by adults as children gradually develop more skills, knowledge, and autonomy. For example, a child may continue to be excited about using the HSE take-home kits, while at the same time the parent (through the workshops and engaging with the kits) begins to broaden their understanding of engineering and starts making connections between the engineering design process and everyday life. Both parent and child are motivated to seek out new engineering-related experiences, facilitated by the parent's growing awareness of different opportunities such as the local science museum or engineering-related books at the library, and the whole family begins to see engineering and problem-solving as something they enjoy doing together.

Children and parents build a tower to protect a chicken from a fox with one of the HSE take-home activity kits.

A Head Start teacher incorporates the HSE activities into their classroom.

What We Are Learning

The ongoing development and testing of the HSE program has created a unique context for studying what engineering can look like with young children and their families, how parents and children develop ongoing interests in this topic, and the types of activities and educational support systems that effectively spark and sustain these interests. Since 2015, we have conducted a series of studies to pilot and improve the program, develop a theoretical model of the family interest system, and explore the patterns and processes of long-term, engineering-related interest development (Pattison et al., 2018).

The research has highlighted three components of interest development that appear to vary across families and over time: parent awareness, knowledge, and values; family engagement with engineering activities; and family use of the engineering design process. Within each of these categories, we have observed important shifts in a subset of families that potentially signal movement to deeper and sustained levels of engineering interest:

- family members seeing engineering everywhere;
- families going beyond HSE to engage with other engineering-related activities and experiences; and
- parents and children taking on new roles as teachers or facilitators of engineering (Pattison et al., 2018).

> *Gracias al conocimiento de la ingeniería hemos estado aprendiendo mucho y saber que todos somos ingenieros desde los más chiquitos de las casa hasta los más grandes.*
>
> *[Thanks to the knowledge shared about engineering, we have been learning a lot—including how we are all engineers, from the youngest in the house to the oldest.]*
>
> —Parent who has participated in the HSE program

In addition, pre- and post-program assessments have shown significant increases in parents' personal interest in engineering, comfort supporting their children's engineering-related interests, and broad understanding of engineering as related to problem-solving in everyday life. Families frequently used the HSE activities and engaged in other engineering-related activities, such as talking about engineering, finding examples of engineering in everyday life, and using engineering skills during play. Similarly, Head Start staff members increased their personal interest in engineering, confidence engaging children and families with engineering activities, and frequency incorporating engineering into the classroom or family programs (Pattison et al., 2018).

> *I really enjoyed being with this program. The program had great ideas for children this age. I like how we read a book and add an activity to it—that helps to retell and talk about the book.*
>
> —Head Start teacher

Families visit the Oregon Museum of Science and Industry to celebrate the end of the HSE program.

Most recently, the team has completed a series of retrospective interviews with 18 Spanish- and English-speaking families one to two years after their participation in HSE (Pattison et al., 2019), when children are in kindergarten or first grade. Analysis of the interviews highlights how the program has catalyzed and supported ongoing engineering-related interests for both parents and children. Families reported broadened perspectives on engineering, ongoing use of the HSE activities and materials over several years, seeking out new engineering-related resources and experiences, and using the engineering design process as inspiration for finding engineering in everyday life. The study also suggests the different factors that influence how families develop interests through programs like HSE, such as family values that may or may not align with program goals, parent perceptions of their roles supporting their children's interests, and life challenges that may disrupt ongoing interests—especially for low-income families with limited resources.

Looking Ahead

The research findings are shedding new light on how STEM interests develop in early childhood and the ways that researchers and educators can make STEM learning experiences more relevant and impactful for Spanish- and English-speaking families from low-income communities. Moving forward, we aspire to a long-term vision of the HSE initiative as a thriving research-practice partnership with the MHCC Head Start community that generates ongoing research findings, inspires other partnerships across the country, and provides tools and resources to empower families to make engineering part of their lives.

In support of this vision, the HSE initiative will launch two new projects. The first will extend the reach of the HSE program in partnership with Metropolitan Family Service (MFS), a community organization that serves low-income, racially and ethnically diverse communities across the Portland, Oregon metro region. With funding from the National Science Foundation (NSF 1930848), TERC, and University of Notre Dame, MFS will adapt the HSE program and activities for MFS's parent and family engagement model. The team will then conduct a three-year design-based research study to better understand how the characteristics of hands-on family engineering activities influence how preschool-age children and their parents engage in the engineering design process.

For the second project, also supported by the National Science Foundation (NSF 1906409), we will extend the existing program within the MHCC Head Start program and continue to investigate the ways families develop interests related to engineering and STEM across contexts and over time. The team will use a design-based implementation research approach (Fishman et al., 2013) and integrated longitudinal case studies to refine the HSE program with a larger group of families to serve as an innovative model for other communities around the country. The expanded program will also advance knowledge about family-level engineering interest development systems and how they can be supported by ongoing, cross-context learning experiences, especially as children transition from preschool into kindergarten.

From our perspective, the HSE program will always be a work in progress. We welcome educators and researchers to adapt and expand the ideas from HSE, which are available on the project website (**https://hse.terc.edu)**. In the future, we hope to collaborate with other communities across the country to explore how the HSE model might be adapted to their needs and goals, and how we can collectively create a learning ecosystem that effectively engages families from all communities in lifelong STEM learning.

AUTHORS

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