HANDS ON

A magazine for mathematics
and science educators

TERC

SPRING 2024

1 Developing an Effective Curriculum for Early Algebra

CONTENTS

Letter from the President

Welcome to Spring 2024 *Hands On!* In these articles you'll see how we value and embrace equity throughout our research and development endeavors by working with educators, peers, and students with varied learning styles and cultures, meeting them where they are and leveraging all that they bring to the table to aid in their long-term educational success.

Developing an Effective Curriculum for Early Algebra is about a K-5 program based on years of research that helps address the challenges that many learners face when taking algebra. The LEAP curriculum introduces algebraic concepts early in the learning journey, via rich math discussions and building on student conjecture.

In *Reaching and Teaching Neurodivergent Learners in STEM*, Jodi Asbell-Clarke speaks about the release of her groundbreaking book on neurodivergent learners. Jodi's research addresses what we need to do to help these learners and how school systems can learn to nurture and leverage their problem-solving abilities to aid in their educational success.

In less than three years, the *Institute for Meta-Synthesis* has held 22 webinars and workshops attended by 2,200 participants, reaching 7,000 scholars worldwide, and developing permanent resources. Follow-up results of a cohort of scholars six months after participation has shown positive results including a book chapter, federal grant proposal and a manuscript.

In *Unifying My Identities: Reflections from an REU Student*, an intern and member of the Choctaw Nation reflects on working with a TERC team of researchers on the Native STEM Portraits project. His internship allowed him to take his Native identity into his education and allow it to influence his ways of knowing and being.

Laurie

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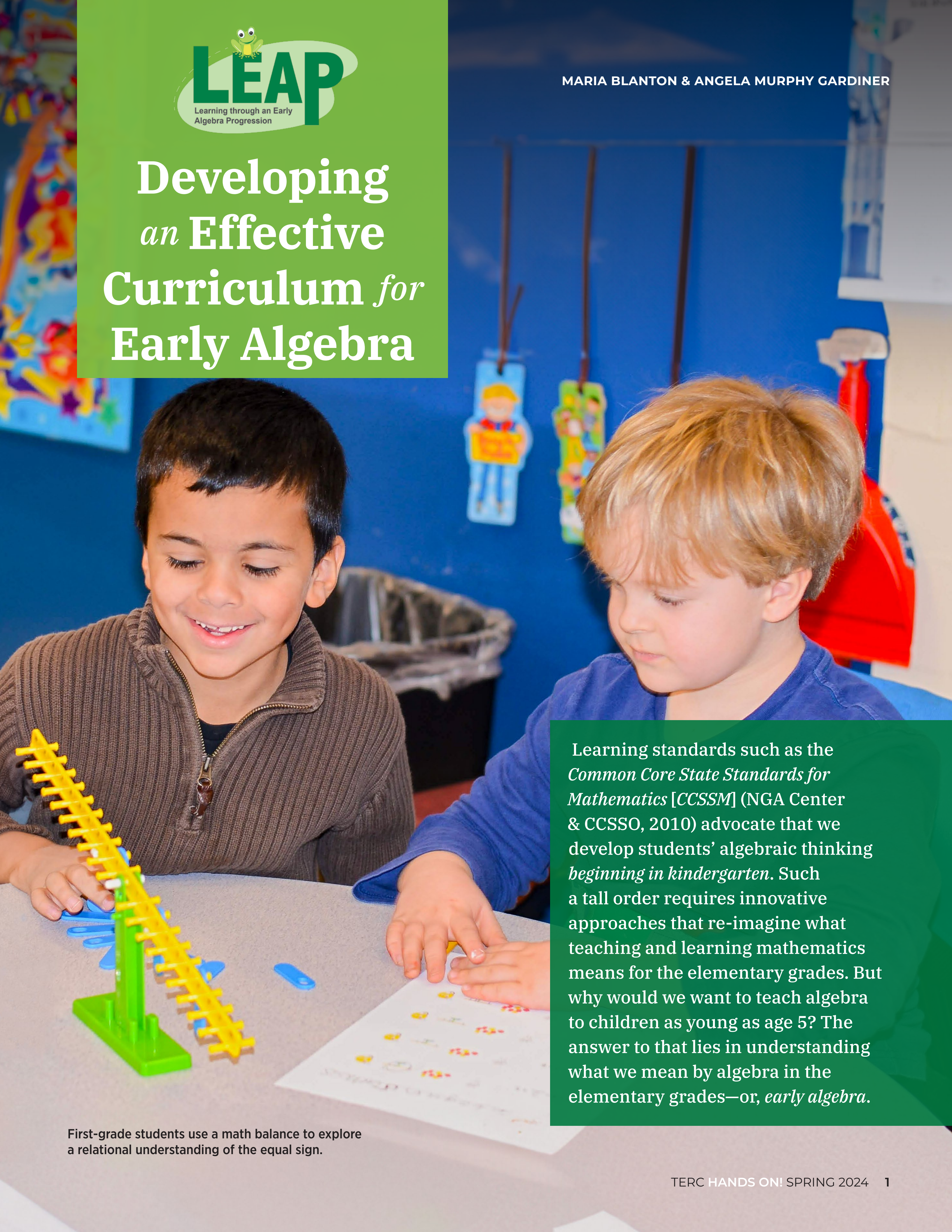
LEAP
Learning through an Early Algebra Progression

MARIA BLANTON & ANGELA MURPHY GARDINER

Developing *an* Effective Curriculum *for* Early Algebra



First-grade students use a math balance to explore a relational understanding of the equal sign.

Learning standards such as the *Common Core State Standards for Mathematics* [*CCSSM*] (NGA Center & CCSSO, 2010) advocate that we develop students' algebraic thinking *beginning in kindergarten*. Such a tall order requires innovative approaches that re-imagine what teaching and learning mathematics means for the elementary grades. But why would we want to teach algebra to children as young as age 5? The answer to that lies in understanding what we mean by algebra in the elementary grades—or, *early algebra*.

What *Algebra* Means for Young Learners

Early algebra can be thought of as a set of four algebraic thinking practices: *generalizing, representing, justifying, and reasoning with* mathematical structure and relationships (Blanton & Gardiner, 2018; Hands On article). From this perspective, early algebra is less about something to *do* (such as solving equations) and more about ways to *think* that involve general mathematical claims. It means noticing that the sum of any two odd numbers is even and building arguments that show why. It involves noticing and representing a relationship between two quantities using words or variable notation, or reasoning relationally with the equal sign to find an unknown value in an equation. It includes understanding how operations behave and using this to compute efficiently.

This might sound familiar. These are all forms of mathematical reasoning that can—and sometimes do—occur in elementary grades. Yet older approaches to teaching elementary grades mathematics have focused on arithmetic content and treated it as distinct from—and to be taught "before"—algebra. Early algebra turns this approach on its head through two core assumptions: (1) young learners cannot fully understand arithmetic *apart from* algebra; and (2) arithmetic in the elementary grades is a natural setting in which students can begin to think algebraically.

Why We Need Effective Early Algebra Resources for Elementary Grades

Early algebra can help mitigate the excessive failure rates in high school algebra that have resulted from older "arithmetic-then-algebra" approaches. This is no small task. Important initiatives—through focused funding opportunities and state-wide policy goals—are bringing new weight to addressing algebra's historic "gatekeeper effect" (Schoenfeld, 1995). But we also need new curricula that use fresh approaches to what it means to "do" algebra in the elementary grades. Even widely adopted elemementary curricula have significant gaps in their treatment of early algebraic concepts (Blanton et al.,

Table 1 | Comparison of Learning Goals for **LEAP K–2** and a Widely Adopted Regular Curriculum (**REG**)

	Learning Goals for Algebraic Thinking Practices	LEAP			REG		
		K	1	2	K	1	2
Represent	**Develop generalizations about**						
	Properties of operations	X	X	X			
	Sums of evens/odds	X	X	X			
	Rules for patterns	X					
	Relationships between quantities	X	X	X			
Generalize	**Express relationships in words for**						
	Expressions and equations	X	X	X		X	X
	Arithmetic relationships	X	X	X			
	Function relationships	X	X	X			
	Express relationships with variable notation for						
	Expressions and equations		X	X			X
	Arithmetic relationships			X			
	Function relationships			X			
	Express relationships as equations in non-standard forms (e.g., a + b = c + d)	X	X	X	X	X	X
Justify	**Explore representation-based arguments for**						
	Claims about specific but uncounted cases	X	X	X			X
	General claims (generalizations)		X	X			
	Identify best arguments (empirical vs. representation-based) for general claims			X			
Reason	**Develop a relational view of = by using concrete representations to**						
	Find if equations in non-standard form (e.g., a = a, a = b + c, a + b = c + d) are true or false	X	X	X	X	X	X
	Find missing values in equations in non-standard form (e.g., a = b + c)	X	X	X		X	X
	Identify properties of operations to explain computational work		X	X			

2019). For example, a relational understanding of the equal sign is a core concept in algebra (and arithmetic). However, this concept is usually addressed primarily in first grade, even though students' operational misconceptions about the equal sign persist throughout elementary and middle grades (Stephens et al., 2013) in ways that can impact their success in algebra (Knuth et al., 2006).

Relational thinking: The equal sign means two quantities are equivalent or the same amount. Students who think *relationally* will describe the equal sign as indicating an equation is "balanced."

Operational thinking: The equal sign means to perform the computation indicated to its left. Students who think *operationally* will describe the equal sign as meaning "the answer" or "the total."

To address these gaps we developed the LEAP curriculum, an early algebra curriculum for Grades K–5[1] that can supplement any existing elementary grades mathematics curriculum. To illustrate this, **Table 1** compares the treatment of algebraic thinking practices in LEAP (Grades K–2) with one widely adopted curriculum. LEAP builds young learners' ability to generalize, represent, justify, and reason with the mathematical relationships embedded in arithmetic content they encounter in elementary grades, with an eye towards the algebra content they will encounter later. Tested in classrooms with diverse learners, LEAP's inclusive approach can improve educational outcomes for *all* students (Blanton et al., 2019): research shows that students who were taught the LEAP curriculum as part of their regular mathematics instruction in elementary grades were *significantly better prepared for algebra* upon entering middle grades (Blanton et al., 2019; Stephens et al., 2021).

Building Students' Algebraic Understanding with LEAP

Through 18–20 hands-on lessons for each of Grades K–5, the LEAP curriculum uses a spiraled approach that expands and deepens the treatment of the four algebraic thinking practices across elementary grades. Lessons are spaced throughout each year to allow for reflection and growth. **Figure 1** provides an overview of the components of a LEAP lesson. LEAP uses a variety of strategies to develop students' understanding of core early algebraic concepts and practices. Let's look at some of these.

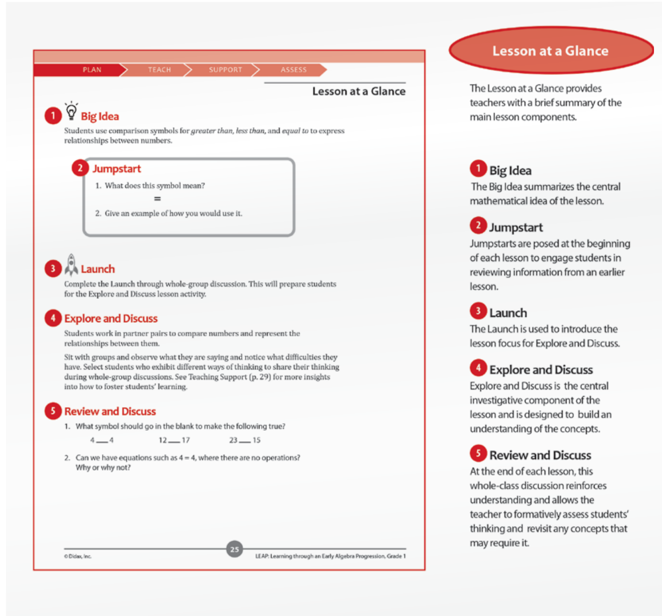


Figure 1 | Components of a LEAP Lesson (reprinted from Blanton et al., 2022b, p. xxiv)

Encouraging Good Classroom Norms

LEAP lessons are built around cognitively demanding tasks that support children's mathematical sense making. The ways in which students participate in math classrooms is critical to this. Beginning in kindergarten, LEAP lessons encourage students to actively explain their thinking, to provide good arguments, and to challenge each others' ideas. Such norms are foundational to building students' understanding. For example, in one Grade 1 lesson, partner groups are asked to consider and discuss the meaning of "even" and "odd" using concrete and visual tools and without counting the cubes (see **Figure 2**).

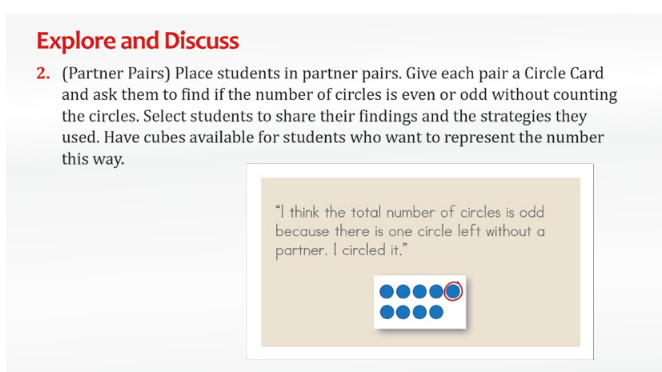
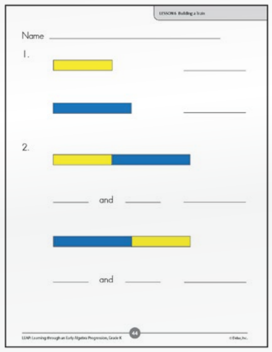


Figure 2 | Grade 1 Partner Exercise on Identifying Evens and Odds (reprinted from Blanton et al., 2022b, p. 6)

Explore and Discuss



1. **How long is your yellow train? How long is your blue train?**
   Place students in partner groups and give each group an activity sheet and two different-colored sets of cubes where the cubes in each set are a single color. (On the activity sheet, the length of the blue train appears longer than the length of the yellow train. You might select a greater number of blue cubes than yellow cubes for the cube sets so that this aligns.) Ask students to build their blue and yellow trains and record their lengths on the activity sheet.
2. **How long is your yellow-blue train? Your blue-yellow train?**
   Ask students to build their new yellow-blue and blue-yellow trains and record the length of each on their activity sheets. Do students find the length of each train separately? Do any students notice that if they know the length of one train, then the length of the other must be the same?
   What do you notice about the lengths of your blue-yellow and yellow-blue trains? Observe what strategies students use. Some students might look at the numbers they have recorded. Others might reason that because there is only one train, the lengths must be the same because they can "flip" the train around.
   Why do you think the lengths of the yellow-blue and blue-yellow trains are the same? Do students notice that the total length does not change because the total number of cubes stays the same regardless of the order in which they count them (blue-yellow or yellow-blue)?
   What do you notice about the numbers you recorded for the lengths of the two-color trains? Do students notice that the value for the length of the combined trains is the same, although the addends are reversed? (For example, "5 and 3" and "3 and 5" are both equal to 8?)

Figure 3 | "Explore and Discuss" Component from a Kindergarten Lesson on Commutativity (reprinted from Blanton et al., 2022a, p. 41)

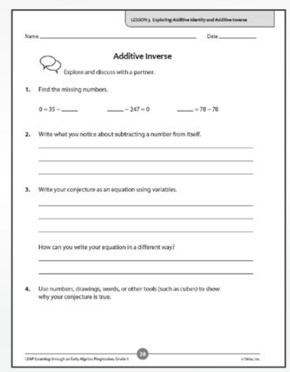
Through simple tasks such as this, teachers can build rich discussions in which students share their ideas and think about and challenge other ideas. In our experience, rich math discussions in elementary grades allow students to discuss new concepts and compare their ideas and strategies to those of their peers, deepening their mathematical understanding. Engaging in mathematical discussions with young learners shows them that there isn't always one way to think about a problem.

Revisiting Core Algebraic Concepts and Practices Across Grades

It takes time for students to deeply understand any concept. Early algebra content is no different. LEAP continually revisits core algebraic practices and concepts across elementary grades. Over time, students develop strong understandings about how to notice, represent, justify, and reason with general mathematical claims, using increasingly sophisticated representations. For example, in kindergarten, children begin to think informally about important properties such as commutativity, even before operational symbols such as **+** are introduced (see **Figure 3**). As students advance in arithmetic work across elementary grades, they begin to generalize these properties, first representing them in words that make sense to them, then in variable notation. They build representation-based arguments (Schifter, 2009) for why their claims about operations are true and they reason with these properties to compute more efficiently.

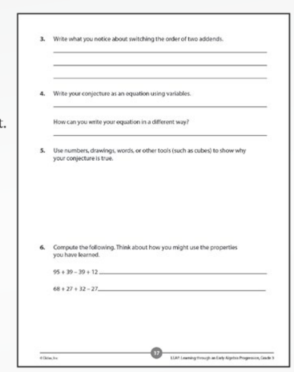
Figure 4 illustrates this with a portion of the "Explore and Discuss" from a Grade 3 lesson that uses true/false and open equations as a context for exploring the commutative property of addition.

Explore and Discuss: Additive Inverse



1. **What is the meaning of the equal sign in these equations?**
   Notice how students think about the meaning of the equal sign. Do they accept that there may be no operation to the left of the equal sign? Encourage students to share responses and justifications.
2. **What happens when you subtract a number from itself?**
   As a class, develop a good conjecture in words that captures what happens when "any number" is subtracted from itself. Again, look for incomplete conjectures ("You get zero") and encourage students to develop clear, complete conjectures. A well-written conjecture ("If any number is subtracted from itself, the result is 0") allows students to more easily translate a conjecture given in words into a variable equation. Continue to discuss the meaning of the term conjecture, and give examples and non-examples of well-written conjectures.

Explore and Discuss



3. **Write a conjecture in words about what you noticed.** Encourage students to share their conjectures about what happens when the order of two addends is switched. Discuss whether students' conjectures are mathematically the same or different. Use students' descriptions of "any number" to discuss the use of letters to represent two arbitrary numbers in preparation for Task 4. Remind students of what makes a good conjecture.
4. **How could you represent your conjecture as an equation using variables?** Students should write a variable equation that reflects the conjecture they developed in their own words. Ask students to share their representations. Make sure students understand why it is important to represent this conjecture using two different variables. Discuss why equations that use different letters ($m + n = n + m$ and $a + b = b + a$) are actually equivalent. Have students describe what their letters represent.
5. **Is your conjecture true for all numbers?**
   Notice whether students develop arguments based on testing whether the equation is true for specific numbers or if they build more general arguments using representations such as drawings or cubes.

Figure 4 | "Explore and Discuss" excerpt from a Grade 3 Lesson on Commutativity (reprinted from Blanton et al., 2021a pp. 32-33)

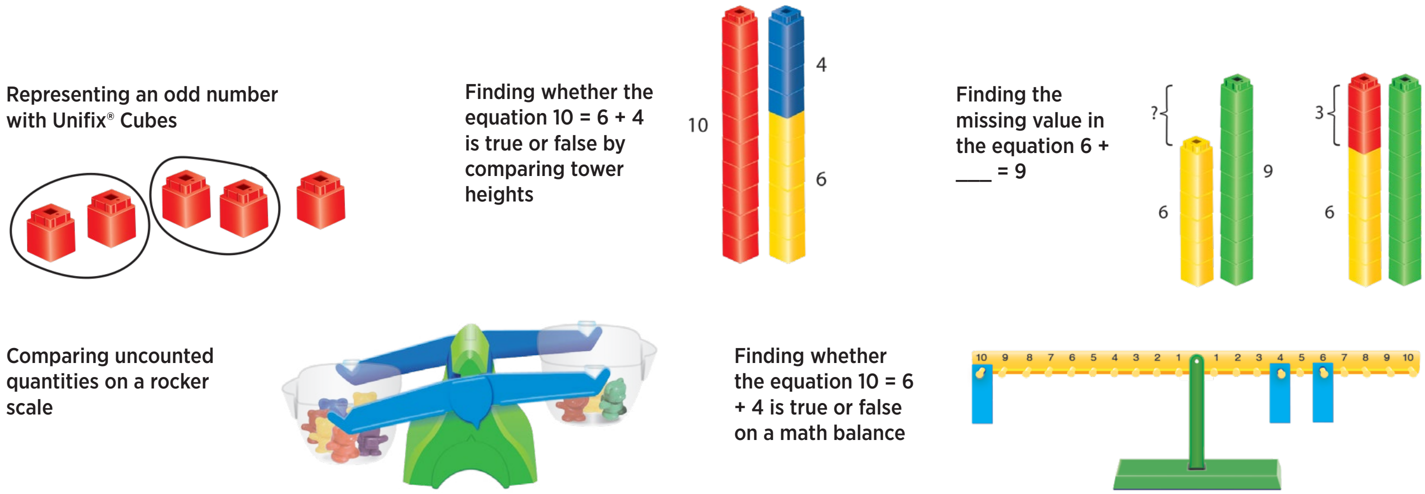


Figure 5 | Different Ways Concrete Tools Are Used in LEAP Lessons (reprinted from Blanton et al., 2022b)

Using Concrete and Visual Tools To Support Learning

LEAP lessons layer the use of tools from concrete to visual to abstract (Witzel & Little, 2016) to help students make sense of algebraic concepts (see **Figure 5**). This is particularly important for younger learners.

Lessons also incorporate visual tools to help students transition from concrete to abstract thinking. For example, in reasoning about whether the sum of two numbers is even or odd, students transition from Unifix Cubes® to visual representations of evens and odds using "circle cards" (see **Figure 6**).

Incorporating Teacher Support in LEAP Lessons

The LEAP curriculum embeds important teaching strategies into each lesson (see **Figure 7**). Lessons also include research-based insights into students' thinking about algebraic ideas, including misconceptions they have and how to address these through instruction. Support materials provide teachers with guidance on how to develop key ideas or use essential teaching practices and how to use various concrete and visual tools to promote learning. They also provide information on the different mathematical conventions or vocabulary students might encounter in lessons. Guided question prompts are included throughout each lesson to help teachers build rich classroom discussions (for example, see **Figure 4**). Multiple formative assessments are included for each grade to measure students' progress.

Conclusion

Effective, research-based curricula such as the LEAP curriculum can bridge the transition from old ways of doing mathematics to new ways of thinking that can improve *all* students' success in school mathematics. Our research has shown that LEAP Grades 3–5 significantly improves children's algebra readiness for middle grades (Blanton et al., 2019) *and* that these students retain their advantage as they progress through middle grades (Stephens et al., 2021). Our recently completed LEAP Grades K–2 curriculum shows similar potential. Our next goal is to study the LEAP Grades K–2 curriculum's effectiveness and how we can best support teachers in implementing LEAP across elementary grades.

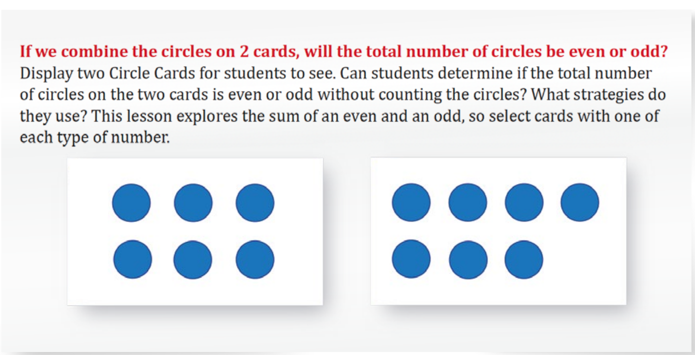


Figure 6 | Reasoning with Visual Tools for Sums of Evens and Odds (reprinted from Blanton et al., 2022b. p. 12)

Teaching Support

Making Good Conjectures

Understanding how to develop good conjectures takes time. Discuss the meaning of conjecture as a mathematical claim that might be true. Students often give partial conjectures such as "The answer is odd." Encourage the development of good, clear conjectures such as "If we combine an odd number and an even number of cubes, the result is an odd number of cubes." Ask students to share their conjectures and use this conversation to model developing good conjectures. While conjectures can (and should) be given in students' own words using simple language, help students think about how to make conjectures clear and complete.

SSL Supporting Struggling Learners

For more strategies to support struggling learners, refer to the chart on page xiii.

Including Other Even/Odd Strategies

Students often bring strategies other than the pairs/leftover strategy to their discussion about evens and odds. Some are less meaningful than the pairs/leftover strategy and simply serve as quick ways to identify a number as even or odd (for example, a number is even if it belongs to the sequence 2, 4, 6, ...). Others, such as an equal groups strategy, can help students think conceptually about even and odd numbers. While **LEAP** lessons focus on a pairs/leftover strategy, it is still important to listen to students' ideas about even and odd. Use this as an opportunity to talk about the advantages and disadvantages of different strategies.

Encouraging Representation-Based Reasoning

Representation-based reasoning uses tools such as drawings or manipulatives to justify a conjecture without appealing to specific numbers or examples. While students might use a specific number of cubes, for example, to depict any even number, their argument does not depend on that number. Encourage students to reason in this more general way.

Mathematical Convention

Students sometimes think of even and odd numbers based on whether a set of cubes representing a number can be divided into two equal groups or not. While this thinking is correct, students who have only this view (and not a pairs/leftover view) may have difficulty making the transition to more formal definitions of even and odd later.

Figure 7 | Teacher Support Materials from a Grade 1 Lesson Exploring the Sums of Evens and Odds (reprinted from Blanton et al., 2022b, p. 16)

Learn More About Project LEAP and the LEAP Curriculum

Please contact us if you are interested in partnering with us in our research or visit our website (terc.edu/projects/project-leap/) to learn more about the LEAP early algebra curriculum and how you can use it in your school or district.

Author Bios

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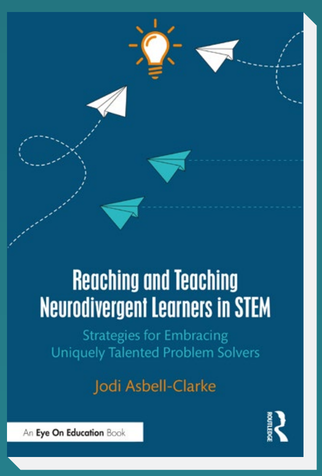
Reaching and Teaching Neurodivergent Learners in STEM

An Interview with Author Dr. Jodi Asbell-Clarke



Reaching and Teaching Neurodivergent Learners in STEM, a new book by TERC researcher Jodi Asbell-Clarke, Ph.D., M.A., M.Sc., encourages educators to embrace the cognitive strengths of neurodivergent learners in STEM (Science, Technology, Engineering, and Mathematics).

An educational researcher and director at TERC, Dr. Asbell-Clarke spent eight years co-teaching with a middle-school STEM teacher in a high-needs school to gather many of the stories and strategies in this book. Her work focuses on game-based learning, computational thinking, and neurodiversity in K–12. Early in her career, she was an onboard software verification analyst for IBM during the first 25 space shuttle missions. She later taught physics and astrophysics at the University of Illinois laboratory school.

We recently spoke with Dr. Asbell-Clarke about her book and its relevance for educators, administrators, and others with an interest in neurodivergent learners.

What inspired you to write this book?

After 30 years in the field of STEM education, I realized that many people, including those in our education system, are unaware of the unique talents inherent in neurodivergent learners. I wanted to share the brilliance I've witnessed when neurodivergent learners tackle STEM problems.

When I say neurodivergent, I'm referring, in part, to learners with autism, ADHD (attention-deficit/hyperactivity disorder), and dyslexia. Nearly one in five school children has an Individual Education Plan for one of these diagnoses. There are also many others who struggle with aspects of school, yet who are very strong problem solvers. For some, this is due to stress, anxiety, and/or depression, all of which are on the rise. But they are still talented learners; they just may need to be taught differently.

Every child enters a classroom with a unique set of strengths and weaknesses. My hope is that the strategies in my book help educators reveal those strengths and support those weaknesses, contributing to the development of an education system that effectively recognizes the diverse abilities of every student.

Beyond the education sector, who else do you think would benefit from reading your book?

I think people in computer science fields, such as AI (artificial intelligence) and cybersecurity, in engineering, and in finance would benefit from reading the book. These fields have a dearth of qualified candidates. They need problem solvers who are creative and systematic, who pay close attention to details, and who remain persistent until a problem is solved. We have a pool of these candidates, but they are going untapped. Too often they are marginalized by an education system that treats them as if they are broken. My book focuses on what we need to do to help get these students through the school system in ways that nurture their specific and important talents. By including neurodivergent learners in the way we teach, we will improve equity in education *and* our future workforce.

"Sadie is the teacher I wrote a lot of the book about." —Jodi

During your research for the book, were there any moments that particularly stood out or surprised you?

Two things surprised me. One was how many of the top CEOs of STEM companies already see neurodiversity as a competitive advantage. And the second was how far our education system still has yet to come to understand the power of neurodiversity in the classroom.

What needs to happen to bring those two things closer together?

On a systemic level, all learners need to be seen as having unique sets of strengths and weaknesses. Our education system must acknowledge the neurodiversity of learners; a one-size-fits-all approach is not effective. Individually, how this plays out in a classroom is structuring student learning time and classroom roles using different pedagogies that are known to reveal neurodiverse learners' strengths, such as project-based learning.

What is project-based learning and how does it benefit neurodiverse learners?

It's when students get to choose a project that interests and motivates them. When done well, project-based learning (PBL) has teachers from various subjects integrating their content within the overarching project.

When I was co-teaching in a high-needs-inclusive classroom, we used PBL to reach each learner in Grade 7. They came to class with so many challenges—cognitive, social, and emotional—but we found that, through PBL, we could engage everyone. Some kids used architecture software to design a dream house; some made dance videos; some made phone cases; and some made cookbooks. With each project, we worked through the design process—coming up with a goal and the steps to achieve that goal, so that we could really be explicit about the problem solving we wanted the kids to learn. By the time these kids were in Grade 9, they designed a new school building and presented their model to the school board and local council as input to an upcoming new build. When given agency and autonomy of their own learning, while still receiving guidance and structure from their teachers, these kids thrived.

What can educators draw from your book to make a swift positive difference in their teaching approach?

There are practical strategies in my book that range from how to reshape schools to how to make an individual lesson you can use tomorrow with your kids. I try to provide actionable information for administrators, teachers, and parents on how to reveal the strengths of neurodivergent learners while also supporting their struggles.

[One strategy is] looking at assessment differently and how you define assessment. By using a real-time assessment during our project-based learning classes, my co-teacher was able to catch excellence in the moment rather than trying to extract it on a test.

[Another strategy is] meeting each learner's needs [by] differentiating the experience. Some students may need a blank page to get started on a problem. Other students may need to dissect a problem someone else has already completed. Others may need to work in a group to hash out solutions before they can get started. Allowing and providing different avenues to success doesn't take away from their ability to learn; in fact, it promotes it.

What do you hope readers will take away from the book?

I hope that each teacher and every reader will have a new lens with which to look at neurodivergent learners. Rather than seeing them as needing to be fixed, this book will give readers strategies to turn the question around and ask how we can change teaching and learning to embrace their differences.

Many of the strengths that are particular to neurodiversity happen to also be exactly what we need for a strong STEM work force. It's on us as educators to create methods to support those strengths—not only for equitable education, but also for an innovative workforce ready to tackle challenges we face as a society.

Reaching and Teaching Neurodivergent Learners in STEM is available for purchase via Amazon and the publisher.

CHRISTINA B. SILVA
NURIA JAUMOT-PASCUAL
MARIA ONG
LISETTE TORRES-GERALD

THE INSTITUTE FOR META-SYNTHESIS

Bringing Meta-Synthesis Methods to STEM Education Research

ORIGINS

In 2020, TERC researchers Mia Ong, Nuria Jaumot-Pascual, Lisette E. Torres-Gerald, and Christina Silva created the ***Institute for Meta-Synthesis: A Practicum Through the Lens of STEM Equity and Inclusion Literature*** (IMS). Their goal was to help scholars build capacity in qualitative meta-synthesis methods and synthesis proposal development skills, with an emphasis on STEM (science, technology, engineering, and mathematics) education equity and inclusion literature.

The four-year project was funded by the National Science Foundation (NSF) Building Capacity in STEM Education Research (BCSER) Program. IMS team members have conducted and published meta-syntheses for over 15 years, focusing on the topics of women of color in STEM, computer science, and engineering higher education (Ong et al., 2011; Ong et al., 2020; Jaumot-Pascual, Ong et al., 2021; Jaumot-Pascual, Silva et al., 2021). This work became the foundation of the activities and other curriculum materials developed for IMS.

Throughout the project, the IMS team offered online and in-person workshops to share their methods for conducting qualitative meta-syntheses. Skills taught included literature searches, like snowballing; literature selection and tracking; deductive and inductive coding; and thematic analysis. The project team developed a series of materials, including a user guide, coaching forms, and demonstrations, to ensure that scholars conducting their own meta-synthesis felt confident in applying these methodological skills to their respective disciplines, regardless of career level or experience with qualitative methods.

Figure 2: Participants learning on Day 2 of the June workshop

DEFINING META-SYNTHESIS

Qualitative meta-synthesis is a set of methods that involves collecting, analyzing, and synthesizing literature reporting on multiple qualitative studies to develop a comprehensive understanding of a particular phenomenon (see Figure 1). It often involves a systematic gathering, review, and assessment of existing qualitative research, with a focus on identifying patterns and themes across different studies. The objective is to create a new interpretation of the literature that goes beyond any single study, generating new insights and knowledge of the phenomenon being explored. Meta-synthesis is used in a variety of disciplines, including education, healthcare, and the social sciences.

Figure 1. IMS's three stages of conducting meta-synthesis

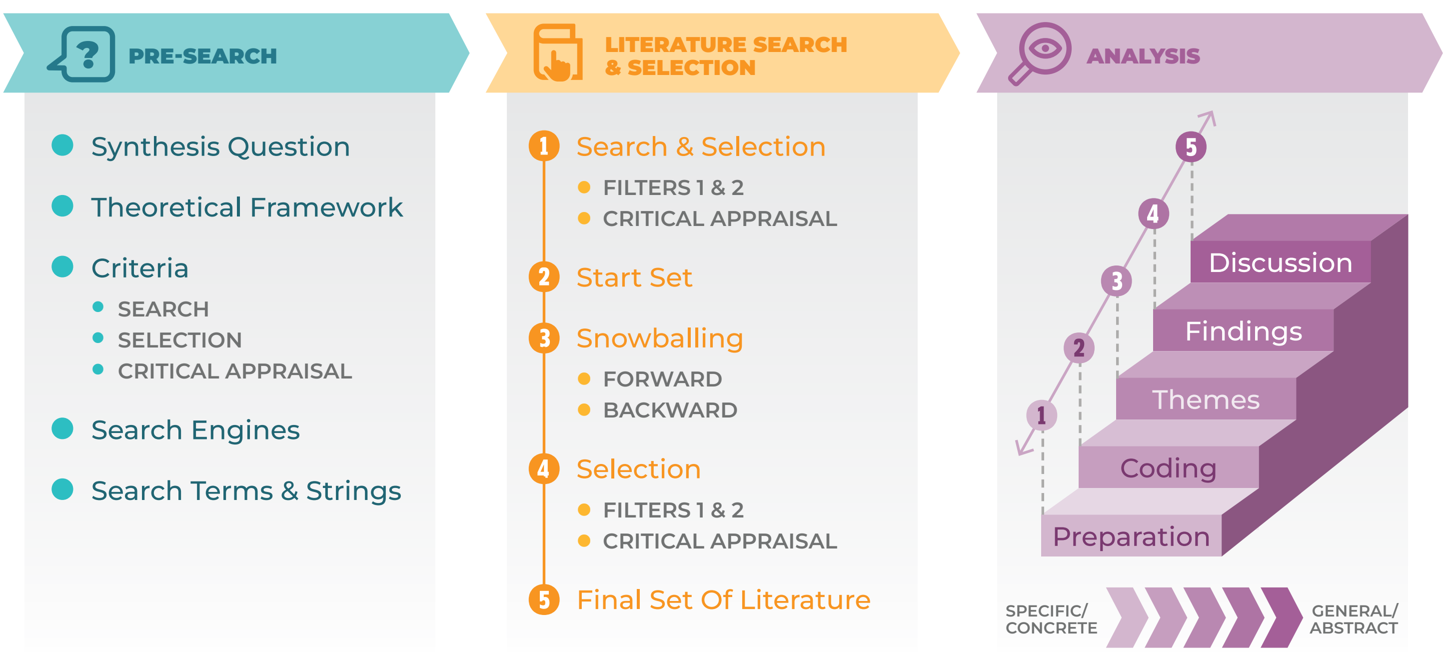


Figure 3: June workshop participants and the IMS team

INSTITUTE FOR META-SYNTHESIS OUTREACH

Between May 2021 and January 2024, the IMS team facilitated 22 webinars and multi-day online workshops, teaching meta-synthesis methods to more than 2,200 participants and reaching nearly 7,000 scholars worldwide. Investigators were recruited and virtually hosted by IMS's partners, including Boston University, Fort Valley State University, the University of Georgia, and the University of Massachusetts at Boston. Two of the webinars were hosted by the American Educational Research Association (AERA): The PEERS (Partnerships for Expanding Education Research in STEM) Data Hub, co-sponsored with the Inter-university Consortium for Political and Social Research; and the AERA Virtual Research Learning Series. Participants gave overwhelmingly positive feedback, praising the IMS offerings as "honest and open," and "easy to follow," and expressing appreciation for "under-the-hood information" and "outstanding" resources. One participant noted, "I have a better—in fact, a brand new—understanding of meta-synthesis, thanks to this workshop, one that has changed my approach to how I will research my topic and plan for future work."

In June 2023, the IMS team offered their first in-person, four-day workshop to scholars from across the country who joined them at TERC in Cambridge, Massachusetts. IMS team members and consultants shared their expertise in specific areas of meta-synthesis, such as using computer-assisted qualitative data analysis software and meta-synthesis publication (see Figures 2 and 3). Participants described the workshop as "transformative," "tremendous," and having "exceeded all expectations." Evaluation data revealed that the workshop gave participants increased clarity and confidence about conducting meta-synthesis.

OUTCOMES OF THE JUNE IN-PERSON WORKSHOP

Following the June workshop, the IMS team gathered scholars as a cohort via Zoom to support one another and to provide updates on their meta-synthesis projects. Emergent outcomes, less than six months later, are noteworthy. One participant turned her meta-synthesis project into the first chapter of her book, which is now in press. She noted, "[Meta-synthesis was] a great way to talk about studies on parental involvement in diverse communities since 1990—just really to get the landscape [of] what is out there on parental involvement in diverse communities." Two other investigators wrote and submitted their meta-synthesis manuscripts to top peer-reviewed journals. Another investigator submitted an NSF CAREER grant proposal, where she proposed meta-synthesis as a main component of her project. Two additional investigators are currently collaborating to test and incorporate artificial intelligence into meta-synthesis memo writing, and one has applied for an internal faculty grant to deepen this work.

WHAT IS NEXT FOR THE INSTITUTE FOR META-SYNTHESIS?

The IMS project will end in September 2024. The team is working diligently on creating permanent resources, focused on equity and inclusion in STEM education, that will be publicly available on its website (www.terc.edu/metasynthesis). These resources will include an updated user guide that provides step-by-step instructions on conducting qualitative meta-synthesis. The website will also contain video demonstrations, templates, and coaching forms to support scholars as they develop their own meta-synthesis.

If you have questions about meta-synthesis methods or if you are interested in attending a future workshop offered by the Institute for Meta-Synthesis, email the IMS team at metasynthesis@terc.edu.

ACKNOWLEDGEMENTS

The authors thank Ada Ren-Mitchell for support with the Figure 1 graphic. Material for the *Institute for Meta-Synthesis, Inside the Double Bind, Engineering Beyond the Double Bind,* and *Literature Analysis and Synthesis of Women of Color in Computing and Technology* projects are based upon work supported by the National Science Foundation under Grants Nos. 2024967, 1760845, 0635577, and 1427129. 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.

Photo credits: Jaclyn Parks

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AUTHOR BIOS

Christina B. Silva (she/her) is a Researcher at TERC. She began her career in STEM education research through her participation in an internship program at TERC offered to undergraduate students who are underrepresented in STEM education. Her research focuses on the lived experiences of people of color, particularly women and girls of color, in STEM education and professions. She currently works on multiple projects, all of which are led by men and women of color, that are grounded in achieving STEM equity and inclusion. She has also assisted on research conducted by the American Institute of Physics TEAM-UP Task Force. She holds a Bachelor of Social Work from Simmons University.

Dr. Nuria Jaumot-Pascual (she/her/ella) is a Research Scientist at TERC and co-leads the Institute for Meta-Synthesis. She researches the experiences in STEM education and careers of populations that live at the intersection of interlocking marginalities, with an emphasis on gender/sexual identity and race/ethnicity. Dr. Jaumot-Pascual has taught research methods to graduate students at Piedmont College and the University of Georgia. She is an ARC (ADVANCE Resource and Coordination) Network Research Board Member. She is a methodologist who specializes in qualitative meta-synthesis and photo elicitation methods. She holds a doctorate in Qualitative Research and Evaluation Methodologies from the University of Georgia.

Dr. Maria (Mia) Ong (she/her) is a Senior Research Scientist at TERC and leads the Institute for Meta-Synthesis. For over 25 years, Dr. Ong has led qualitative and mixed-methods research focused on equity and inclusion in higher education, including four synthesis projects. Her research findings have been published in numerous journals, including the *Journal of Research in Science Teaching, Harvard Educational Review,* and the *Journal of Engineering Education*. She has extensive experience teaching qualitative research methods at schools such as Harvard, Vanderbilt, MIT, and Boston University. She has held advisory roles at the National Science Foundation, the American Institute of Physics, and the National Academies of Sciences, Engineering, and Mathematics. Dr. Ong holds a doctorate in Social and Cultural Studies in Education from the University of California at Berkeley.

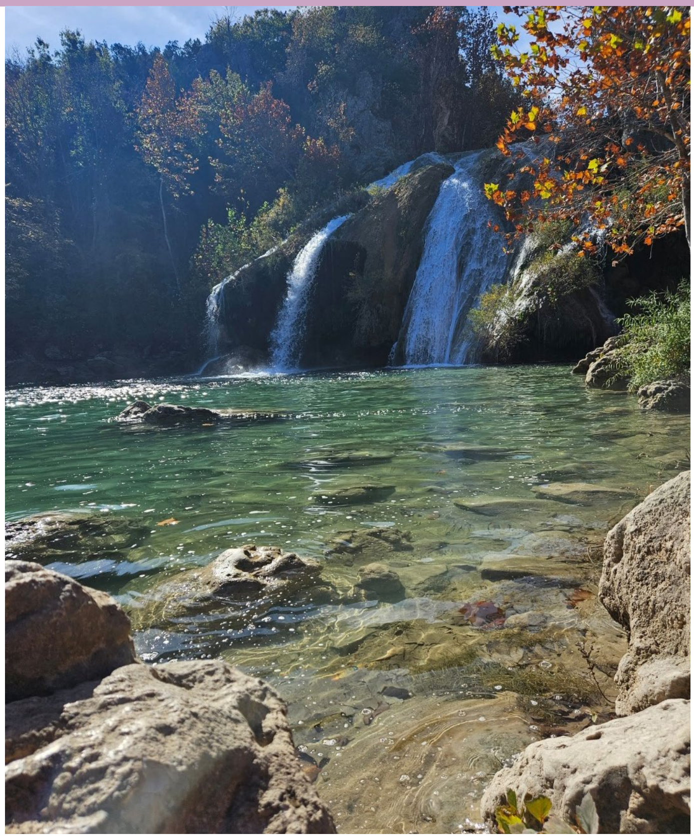
Dr. Lisette E. Torres-Gerald (she/her/ella) is a trained scientist and disabled scholar-activist who is a Senior Researcher at TERC and the Director of Operations and Communication for the new national NSF AISL equity resource center called the Reimagining Equity and Values in Informal STEM Education (REVISE) Center. Her research focuses on addressing racialized gender justice and disability in science and higher education. She is a co-founder of Sines of Disability and the National Coalition for Latinxs with Disabilities (CNLD). Lastly, she has been identified as an AERA/Spencer Foundation Early-Career Scholar and a Kavli Foundation Sponsored Network Leader for Inclusive Science Communication. Dr. Torres-Gerald has a doctorate with a Certificate in Social Justice from the School of Education at Iowa State University and an M.S. in Zoology with a Certificate in Ecology from Miami University.

Unifying My Identities

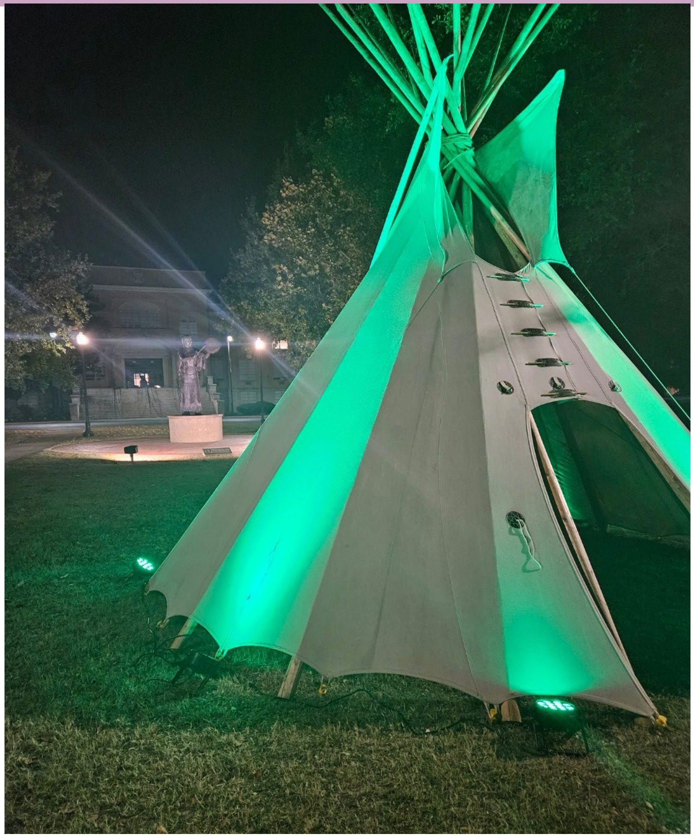
Reflections from an REU Student

DEVON LOCKE

As an enrolled member of the Choctaw Nation, I experienced unanticipated culture shock during my transition into academia as an undergraduate student double majoring in Environmental Science and Political Science at the University of Science and Arts of Oklahoma. Despite being immersed in Native ways of being, I had doubts about my real connection with my culture. I thought that the perspectives carried by my community were universal and self-evident. However, at my university, where I was surrounded by people who did not reflect the same ideals, I learned that some of my values were uniquely connected to my culture. I specifically saw this in classes where we discussed the ethics of environmentalism and environmental justice. Many of my peers expressed perspectives which I felt were continuing ideals of colonialism and I struggled to express my own voice among the different perspectives.



On a hike at Turner Falls



Tipi and a statue of Te Ata, a famous Native American woman who attended my university, University of Science and Arts of Oklahoma

Although I eventually found a steady foothold at my institution, I still avoided exploring why I continued to feel a lack of connection between my Native identity and my majors. I learned how to conduct research but had little experience approaching research with cultural nuance. At the end of the 2022 fall term, my advisor recommended that I apply to the TERC Research Experience for Undergraduates (REU) program. He noted how important this experience would be for my professional development and how it would allow me to examine the ways in which other Native individuals navigate STEM and higher education.

Because of my lack of experience in social science research, I assumed that I would be automatically rejected; I also continued to doubt the strength of my identity and the chance that I would feel any connection to those who truly were connected to their culture. But I hesitantly began the application process. To my surprise, I was accepted, and it immediately felt right to pursue this experience. I did not anticipate the way the REU would provide me with a deeper understanding of research and analysis as well as a reimagining of the way I engage with both my cultural and STEM identities.

I applied for a project called *Native STEM Portraits* (NSP), a longitudinal study that investigates the support and barriers experienced by Native individuals in STEM higher education and professions. The project utilizes a mixed-methods approach, exploring responses from surveys and photo elicitation (PE) interviews. Aspects of this project were way out of my scope of comfort, as my previous academic research experiences were rooted in the traditional Western norms of science. My work drew on the data gathered by the NSP study and utilized Kirkness and Barnhardt's (1991) theoretical framework of the 4R's (respect, relevance, reciprocity, and responsibility), along with Brayboy's (2005) TribalCrit, to complete a full analysis. Specifically, I decided to explore how Native American undergraduates in life and earth sciences view their educational experiences and institutions, using descriptive analysis of the survey data and thematic analysis of the PE interview data.

Reflecting on this internship, I can see the changes in my self-perception as a Native scientist with the passing of each week. At first, I navigated quantitative data that felt familiar. This allowed me to start out with confidence, as I knew that I had the ability to give an appropriate and thorough analysis. As I

AISES Presentation with my parents

Goggled up for lab research

built confidence in my research, I began to read through Native literature and theoretical frameworks to better understand the de-colonized approach to analysis. I began to see my identity reflected in the literature. Finally, some of the isolation I had experienced in my STEM education was being communicated by others in the field of science education. It affirmed for me that my identity was an evolving piece of my academic journey, in much the same way it seemed to be for these authors.

After wrapping up my survey data, I moved onto the qualitative data analysis. Doing a well-rounded analysis of interview data was beyond any previous research experience I'd had. I decided to jump into reading the PE interviews, putting my research questions on the back burner, so that I could humanize the participants and view their full stories as unique testaments to themselves and their identities. Reading through the interviews showed me the manifestation of a Native identity in academia in a way which reflected on my experience. Following the initial read-through, I applied my newly acquired qualitative research training and coded the interviews to reflect their journeys and stories.

As a result of the NSP REU summer, I am more comfortable expressing my cultural values as part of my academic journey. NSP has given me permission — which I did not realize that I felt that I had needed — to take my Native identity into my education and allow it to influence my ways of knowing and being. Additionally, NSP and the REU summer has provided me with extensive experience by funding me to present at two national conferences, AISES and SEEDS, which allowed me to be immersed in the field of academia and become more comfortable in my identity and understanding.

THANKS

I am exceedingly grateful for the mentorship I received at TERC. Dr. Mia Ong, Dr. Nuria Jaumot-Pascual, Dr. Lisette Torres-Gerald, Dr. Matthew Madison, Dr. Selay Zor, and Dr. Tiffany Smith offered me extensive support. They addressed each question I had and gave me wonderful articles to continue exploring. Christina Silva provided me with unique near-peer mentorship that has helped me develop professionally. Dr. Stephen Alkins and Bengisu Onal helped me explore how to take my research beyond this program. Each person mentioned above pushed me further than I thought I was capable of going and made sure that I had the support to produce the best research product. This work was funded by the National Science Foundation through Grants 2000619 and 2150364. Any opinions, findings, and conclusions or recommendations expressed in this material are the author's and do not necessarily reflect the views of the National Science Foundation.

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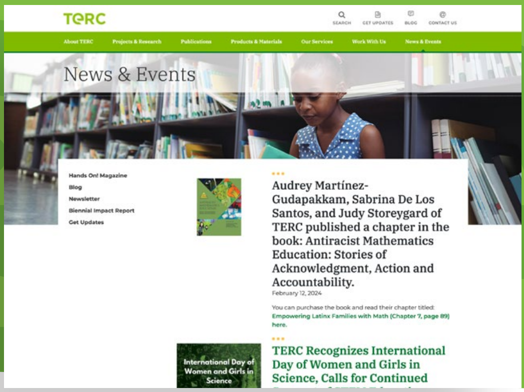

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terc.edu/news-events

INFACT Materials

https://tinyurl.com/y29n29sc

INFACT is a teaching and learning program for learners in grades 3–8, freely available for use.

INFACT offers a broad variety of computational thinking (CT) materials, organized into customizable sequences that thread through the core ideas of CT, including Problem Decomposition, Pattern Recognition, Algorithm Design, Abstraction, and Debugging. Embedded with supports for executive function and social-emotional learning.

Mia Ong joined the National Academies Leadership and Advisory Committee for the Action Collaborative on Transforming Trajectories for Women of Color in Tech

https://tinyurl.com/mv6wycz7

The *Action Collaborative on Transforming Trajectories* is made up of 34 member institutions from industry, higher education, and national laboratories that have pledged to support the advancement of women of color in tech.

NEW PUBLICATIONS

Supporting Students with Blindness and Visual Impairments to Learn Computational Thinking Through Astronomy

Eric D. Hochberg, James K. L. Hammerman, & Santiago Gasca

https://doi.org/10.5241/14-254

Audrey Martínez-Gudapakkam, Sabrina De Los Santos, and Judy Storeygard of TERC published a chapter in the book: Antiracist Mathematics Education: Stories of Acknowledgment, Action and Accountability

Martínez-Gudapakkam, A., De los Santos, S., Storeygard, J., Patrone, A., Cuevas, D., & Chingo, P. (2023).

https://tinyurl.com/5afwhknp

Chapter 7: Empowering Latinx Families with Math, offers practices that promote inclusion and reflect the importance of a collaborative approach to antiracist mathematics education. What a gift to those who work in mathematics education and recognize the need to transform business as usual.

Andee Rubin appointed to the National Academies of Sciences, Engineering, and Medicine committee

https://tinyurl.com/5bd2s5r8

The committee will conduct a consensus study that will identify competencies needed for people to navigate and succeed in the changing computational landscape and the role that K-12 education can play in the development of these competencies.

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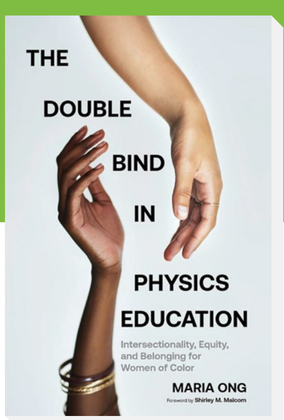
Featuring Two New Books by TERC Authors



The Double Bind in Physics Education: Intersectionality, Equity, and Belonging for Women of Color

by Mia Ong

An incisive study of the mechanisms reinforcing the underrepresentation of women of color in STEM fields and a call for systemic change to address the imbalance.

Centering and relaying the experiences of women of color in physics through their lenses and voices ... Ong masterfully illuminates barriers and navigation strategies that inform us all on how to ensure positive career trajectories for everyone.

— Gilda Barabino, president, Olin College

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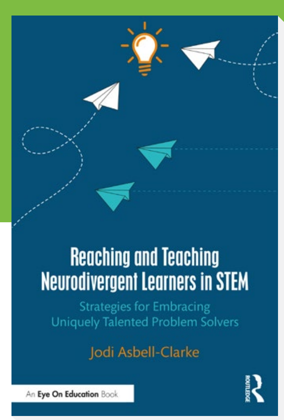

Reaching and Teaching Neurodivergent Learners

by Jodi Asbell-Clarke

Strategies for Embracing Uniquely Talented Problem Solvers

Imagine a world where the unique STEM-related talents of neurodivergent individuals are cultivated to grow a dynamic, innovative workforce In her groundbreaking work, Jodi Asbell-Clarke presents an empowering roadmap for educators to embrace and nurture these talents, instead of perpetuating shame and pity.

—Professor Sara Seager, MIT

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