

Exploring Our World of Math: Empowering and Inspiring Students with Authentic Learning

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Introduction

Mathematics is everywhere. In both our personal and professional lives, mathematics is all around us. It is in the complex work of urban planning, the air flow engineering of an airplane’s cabin, the comparing and contrasting of gasoline-powered versus electric vehicles, the health and environmental analysis of pesticides used on crops, the motion tracking and design of virtual reality experiences created to teleport students and adults to immersive experiences that would never be possible in the real world, and so much more. As educators, it is our job to help illuminate the invisible forces of math all around us. Such illumination requires engaging students in authenticity or authentic learning. Authentic learning experiences that occur during core mathematics instruction can either take place in the real-world or have direct applicability to real-world contexts. Both options let students “experience the same problem-solving challenges in the curriculum as they do in their daily endeavors” (Herrington et al., 2014, p. 402).

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The big idea is that the problem is grounded in the real world but open for interpretation, complex enough to require sustained work with the help of peers, layered to require reflection, and results in a variety of tangible solutions.

—(Roberts & Chapman, 2017, p. 16)

Inspiring, authentic learning opportunities are indispensable for students for a multitude of reasons:

- **Authenticity cultivates belonging** in mathematics (and STEM more broadly) and empowers students to become solution seekers inspired to make our world better (as described in Jackson, Cook, et al., 2024; Jackson, Roberts, et al., 2024).
- **Authenticity fosters integrated learning** by providing tangible opportunities for students to witness and appreciate the utility of mathematics in their daily lives.
- **Authenticity enriches effective teacher and student mathematics practices** through intentional opportunities for students to experience mathematics in high-quality, context-rich ways.

Sample Authentic Contexts in <i>California Reveal Math</i>[®]		
Authentic Learning Context	Connecting to the Mathematics	Grade Band
Animals in the World Around Us	Sorting, Data Analysis, Addition and Subtraction Strategies	K–2
Transportation	Measurement, Addition and Subtraction	K–2
Recycling	Data Collection	3–5
Groceries	Estimating Decimals	3–5
City Planning	Scale, Geometry, Proportional Reasoning, Angles	6–8
Gasoline vs. Electric	Linear Expressions and Equations	6–8
Bicycle Sharing	Linear and Nonlinear Functions	9–12
Sustainable Building	Polynomial Equations	9–12

Authenticity Cultivates Belonging

The concept of cultivating belonging in STEM is not new. In fact, the United States Department of Education has promoted this idea through the “YOU Belong in STEM” campaign, part of the Raise the Bar: STEM Excellence for All Students initiative (United States Department of Education, 2022). Authenticity is a key means through which we can empower every student to see themselves as a doer of math. By connecting mathematics to their histories and experiences, they can begin to contribute in ways that build from their strengths and cultural backgrounds and grow as confident and capable problem-solvers. Every student belongs in mathematics and STEM, regardless of whether they ultimately pursue a STEM-centric career.

When students engage in authentic learning, they can more readily witness the joy, wonder, and beauty of mathematics (see NCTM, 2018, 2020a; 2020b). Experiencing mathematics firsthand is far more powerful than reading about it in a book. When students authentically explore the mathematics happening all around them, which often remains hidden until illuminated by their teachers, they can begin to build confidence in their real-world understanding of mathematics and become active participants in their learning. There are many strategies we can employ and resources available to us as educators to cultivate a positive sense of belonging:

- The resource “I Am a Scientist” shares the diverse life stories and scientific accomplishments of professionals in a wide variety of STEM careers to ensure that “every student [can] see themselves in science” (I Am a Scientist, 2024). This resource (<https://www.iamascientist.info/>) focuses on breaking stereotypes, prioritizing representation, demystifying career pathways, humanizing science, and connecting STEM to society. The website can be used to link mathematics concepts students are learning in class to real-world applications and career paths so that they can begin to envision and work toward their future in STEM.
- The resource “The unCommission” (Powered by 100K in 10) identified three insights key to establishing equitable STEM education in the United States (Beyond 100K, 2024). First, youth want to make a difference through STEM. Second, it is critical that youth feel a sense of belonging in STEM. Third, teachers have the greatest ability to cultivate that sense of belonging. On their website (<https://theuncommission.org/>), educators can search using different demographic and geographic filters to access STEM stories from hundreds of teens and young adults. With this resource, you can locate and share stories that may resonate with your students based on their interests and backgrounds. We suggest that teachers control use of this resource because not all crowdsourced content may be fully vetted.
- Inviting local STEM professionals to be guest speakers or mentors can go a long way in developing students’ sense of belonging in mathematics and STEM. Empowering students to meet and interview people who directly impact their community brings the world of mathematics directly into the classroom. Consider reaching out to those working in industry, non-profit, local government, new technology, innovation incubators, and more (Bush & Cook, 2025). Specifically consider community members with diverse perspectives and those who have a clear story of

overcoming challenges to get where they are today. Students benefit from seeing that they can arrive at success in many different ways and that the pathway is not always clear-cut or linear.

- Consider teaching mathematics ideas alongside STEM-centric literature for children and young adults to help forge authentic connections and structure exploration. There are countless examples of STEM-centric literature for students, but one of my favorites is a book series entitled "Powerful Mathematicians Who Changed the World" (edited by *Reveal Math*[®] author Christa Jackson, 2023), which highlights diverse mathematicians and their authentic contributions to the world.

Authenticity Fosters Integrated Learning

Authentic learning naturally lends itself to an integrated approach. As students explore mathematics in authentic ways, they are learning about its role and implications in many fields, careers, and aspects of our everyday lives (Bush & Cook, 2025). For example, mathematics plays an essential role in nature, medicine, athletics, music, engineering, home improvement projects, social media and influencer algorithms, and so much more.

You may be familiar with integrated approaches that have become commonplace and that, depending on their implementation, may fall under the umbrella of authentic learning. These include Inquiry-Based, Problem-Based, Project-Based, Place-Based, Real-World, Situation-Based, Engineering Design, Design Thinking, and more. If your school has adopted one of these approaches, it makes sense to consider how authentic learning in mathematics fits within that approach. Most important, though, is that students have high-quality experiences authentically exploring mathematics.

Integrated learning, and specifically integrated STEM learning, can improve student outcomes in STEM in a variety of ways (Bybee, 2013; National Research Council; 2011, 2013). Integrated STEM learning enables students to develop 21st century learning skills and the skills they need to succeed in today's workforce (Atkinson & Mayo, 2010). It prepares students to become STEM-literate, problem-solving members of society (Mohr-Schroeder et al., 2020, Zollman, 2012) and increases access and opportunity to STEM for all (Jackson et al., 2021). In addition, a recent federal report by The National Science and Technology Council (part of the Executive Office of the President), titled "Convergence Education: A Guide to Transdisciplinary STEM Teaching and Learning" (2022), describes the need for integrated learning that is transdisciplinary and "driven by compelling or complex socio-scientific problems or topics, where learners apply knowledge and skills using a blended approach across multiple disciplines... to create and innovate new solutions" (p. 13)—all of which is at the heart of authentic learning. Further, a joint position statement released by NCSM: Leadership in Mathematics Education and the National Council of Teachers of Mathematics entitled "Building STEM Education on a Sound Mathematical Foundation" (2018) encourages educators to "look for opportunities to integrate science, technology, and engineering in meaningful ways as students tackle problems involving mathematics in relevant settings" (p. 5).

When integrating mathematics with other disciplines in your classroom, don't feel as if you must

have all the answers. While retaining a deep focus on mathematics, openly explore the connections to various disciplines and careers and learn alongside your students. In other words, you don't have to be an engineer, dietician, environmentalist, surgeon, network scientist, information analyst, biostatistician, artificial intelligence expert, or biotech entrepreneur to explore with students how mathematics is used in these roles (Bush & Cook, 2025). All the information available at our fingertips makes it easier than ever before to explore, learn, and grow together.

Authenticity Enriches Effective Teacher and Student Mathematics Practices

In the landmark publication, "Principles to Actions: Ensuring Mathematical Success for All" (2014), the National Council of Teachers of Mathematics identify eight teaching practices “which represent a core set of high-leverage practices and essential teaching skills necessary to promote deep learning of mathematics” (p. 9). Please see Principles to Actions (NCTM, 2014) and, for further information, the Catalyzing Change Series (NCTM, 2018, 2020a, 2020b) for an in-depth discussion of each practice and both teacher and student actions related to each practice. The table that follows lists each practice, reinforces existing ideas, and provides suggestions for using practices specifically when engaging students in authentic learning. In addition to the eight effective teaching practices, authentic learning provides opportunities to engage students in the student mathematical practices (CCSSO, 2010) within the contextual problem under investigation.

Authenticity and the Mathematics Teaching Practices	
Mathematics Teaching Practice (NCTM, 2014)	Ideas, Strategies, and Questions to Guide Authentic Learning Opportunities
Establish mathematics goals to focus learning.	<ul style="list-style-type: none"> ■ Think creatively while keeping the mathematics learning goals at the forefront of authentic learning opportunities. ■ Consider how you will continually formatively assess mathematics goals in the context of authentic learning.
Implement tasks that promote reasoning and problem-solving.	<ul style="list-style-type: none"> ■ What authentic learning connections can you incorporate into high-level tasks you already use? Are there additional reasoning questions or problem-solving components you can add to existing tasks that engage students in authentic learning? ■ Consider how you can promote mathematical reasoning and problem-solving through the entry-point of a contextual task, issue, or problem under investigation.

<p>Use and connect mathematical representations.</p>	<ul style="list-style-type: none"> ■ Brainstorm an authentic learning opportunity for your students. What mathematical representations would be helpful and meaningful to students to make sense of both the authentic context and the mathematics? ■ How could using multiple representations and students making connections across those representations help deepen the impact of an authentic learning opportunity?
<p>Facilitate meaningful mathematical discourse.</p>	<ul style="list-style-type: none"> ■ In what ways will your whole-class, small-group, peer-to-peer, and teacher-to-student discourse include conversation that links the authentic context to the mathematics and the mathematics to the authentic context? ■ In what ways can mathematical discourse facilitate a sense of belonging and confidence in mathematics and STEM? How can classroom discourse around authentic learning continually connect to the application of mathematics and explore ideas students are curious about?
<p>Pose purposeful questions.</p>	<ul style="list-style-type: none"> ■ As you develop purposeful questions to advance and assess student thinking, in what ways will asking questions in relation to the authentic context help empower students as problem-solvers? ■ What are some sample sentence stems or questions you can think of that either assesses or advances student thinking within an authentic learning experience (capturing both the mathematics and context)?
<p>Build procedural fluency from conceptual understanding.</p>	<ul style="list-style-type: none"> ■ Consider the points during an authentic learning experience where you will conceptually dig into the mathematics, where you will build procedural fluency from conceptual understanding, and during which students will consider the mathematics in authentic context. ■ How can conceptual understanding and procedural fluency build a greater appreciation for the mathematics revealed during authentic learning opportunities? How will this be highlighted with students?

Support productive struggle in learning mathematics.	<ul style="list-style-type: none"> ■ Consider an authentic learning opportunity and think about points at which students might get stuck or struggle. What supports, both mathematically and contextually, can you put into place to support their learning? ■ How might an authentic learning opportunity remove barriers to learning mathematics? What potential new barriers should you be on the lookout and ready for?
Elicit and use evidence of student thinking.	<ul style="list-style-type: none"> ■ As you elicit and use evidence of student thinking, how can you honor the contextual past experiences that students bring to the authentic learning opportunity? ■ As you elicit and use evidence of student thinking, how can you ensure a variety of perspectives, possible solutions, and strategies are encouraged and valued?

California Context: The 2023 Mathematics Framework and Authenticity

The Mathematics Framework for California Public Schools (Mathematics Framework) (CA DOE, 2023) encourages learning experiences in which students are deeply engaged with authentic mathematics and experiences in which they grapple and investigate situations or problems they wonder about. Further, the framework promotes authentic problems grounded in one or more Big Ideas and multiple content and practice standards.

As students engage in authentic learning, Chapter 4 of the framework articulates the types of authentic contexts with which students should engage, including those that:

- Connect to their everyday lives at home, school, and in their community.
- Are meaningful and center on notions of fairness and justice.
- Could be related to social problems or policies or the environment.
- Involve studying publicly available data and using digital tools to explore mathematics ideas in their everyday lives (middle school).
- Feature nonmathematical contexts and use data and modeling approaches (high school).

Further, the framework emphasizes that authentic learning should have a real purpose, be relevant to students, and foster meaningful discussions about mathematics.

Conclusion

As you prepare for your next unit or lesson, consider how you can integrate authentic, transformative mathematics learning experiences into your instruction. Whether by inviting guest speakers to discuss their STEM journeys or illuminating mathematics in our world through community needs, research, and stories, your students will benefit immeasurably from discovering mathematics all around us. We hope this white paper will serve as a helpful tool as you engage your students in authentic learning of mathematics!

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