

What Is STEAM and Why Does It Matter?

Why does STEAM teaching and learning matter? This chapter introduces the fundamentals of STEAM education and shares how building STEAM inquiries around three guiding principles—the Es of **equity**, **empathy**, and **experience**—creates transformative and effective learning opportunities for students. This chapter addresses the following questions:

- **Why should I care about STEAM? What does the research say?**
- **How does STEAM help me achieve equity for each and every learner?**
Learn the importance of embedding STEAM education in the regular school day, making it accessible to each and every learner.
- **Why is empathy central to meaningful STEAM inquiries?** Determine how you can create purpose-driven STEAM inquiries that anchor your mathematics and science instruction and also aim to improve life for others.
- **What experiences are students engaged in when learning STEAM?**
Consider the academic needs of your students and how STEAM is uniquely positioned to meet those needs.

This chapter will also give you opportunities to pause and reflect on your own STEAM journey.

The career of an elementary teacher is equal parts exciting and daunting. Let's acknowledge the tall order that comes with being responsible for teaching many different subjects. We contend that with STEAM we flip the script on the challenges of time, resources, and expertise that you face and instead channel your preparation as a generalist to create amazing learning opportunities for students.

Introduction



Core STEAM Idea

Defining STEAM: What does the research say?

We imagine you might be interested in STEAM learning for many different reasons. Perhaps you keep hearing about STEAM in educational settings, among colleagues, on social media, or through your professional organization. Maybe you bought this book because you are interested in learning strategies for better connecting multiple subject areas to make the most out of your limited instructional time. Or you might be reading this because your school or district is embarking on STEAM to create transformative learning experiences for students that will prepare them for future careers that, let's face it, do not even exist nor can we even imagine. Other important reasons might include wanting to deepen your students' mathematics and science learning or looking for ways to engage each and every one of your students in authentic problems. If any of these reasons make you think "That's me!," you've come to the right place. Our work in STEAM education focuses on integrated learning. For an elementary teacher, there are never enough hours in the day. By integrating subject areas in STEAM, standards across the subject areas can be addressed simultaneously. This book serves as a professional learning tool to guide your journey in using your state's content standards in mathematics and science to drive your development of meaningful and authentic STEAM inquiries.

You might be wondering this: Does integrated instruction work? Will integrating the subject areas be beneficial for my students? Will my students' learning and academic achievement increase as a result? Before STEAM became all the rage, experts have shared how the integration of the STEM subjects can improve a variety of student outcomes in the STEM disciplines (as suggested by Bybee, 2013; Czerniak, 2007; Kennedy & Odell, 2014; Mohr-Schroeder, Bush, & Jackson, 2010; National Research Council, 2011, 2013; Park Rogers & Abell, 2007; Wang, Moore, Roehrig, & Park, 2011). Integrated STEM learning

- Prepares students to become innovators, problem solvers, and citizens who are STEM literate (see Bybee, 2010; Zollman, 2012, for definition; National Academy of Engineering & National Research Council, 2014)
- Positions students to learn successful skills for today's workforce, including solving problems that require the use of multiple subject areas as well as 21st century learning skills (Atkinson & Mayo, 2010)
- Is advocated for in standards such as the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) as evidenced in the Science

and Engineering Practices by intentionally focusing on engineering practices that students should develop so that they deeply engage in rich science inquiry and through direct connections to progressive mathematics content and practice standards in every state. Regardless of the standards your state uses, all states have a list of process or practice standards (e.g., Common Core State Standards Initiative, 2010), which are skills and attributes we should work diligently to develop in our students. See Table 1.1.

Table 1.1
Science and Engineering Practices and Standards for Mathematical Practice

Science and Engineering Practices	Standards for Mathematical Practice
Asking Questions and Defining Problems	Make Sense of Problems and Persevere in Solving Them
Developing and Using Models	Reason Abstractly and Quantitatively
Planning and Carrying Out Investigations	Construct Viable Arguments and Critique the Reasoning of Others
Analyzing and Interpreting Data	Model With Mathematics
Using Mathematics and Computational Thinking	Use Appropriate Tools Strategically
Constructing Explanations and Designing Solutions	Attend to Precision
Engaging in Argument From Evidence	Look for and Make Use of Structure
Obtaining, Evaluating, and Communicating Information	Look for and Express Regularity in Repeated Reasoning

Sources: Common Core State Standards Initiative (2010); NGSS Lead States (2013).

Importantly, though, there is also evidence showing the positive effect of integrated STEM instruction on student achievement (Roehrig, Moore, Wang, & Park, 2012). For example, in a meta-analysis (statistical analysis that combines the results) of 28 studies that examined the effectiveness of integrated STEM instruction, Becker and Park (2011) found a positive effect on student achievement. In another meta-analysis of 31 studies, Hurley (2001) found a positive effect on student achievement in both mathematics and science when the subject areas were integrated.

Teaching Takeaway
Research shows a positive effect on student learning of mathematics and science when the subjects are integrated.

Despite the promise that integrated STEM learning holds to be academically beneficial, it is not implemented widely. In addition to academic factors, the shortfall of STEM graduates (and majors) in the United States (National Science Board, 2016) is also related to students' lack of interest in STEM and even more so for diverse learners (President's Council of Advisors on Science and Technology [PCAST], 2010). In short, because of the promise integrated STEM holds to

increase students' academic achievement in mathematics and science, the lack of interest in STEM warrants bringing new ideas to the table—such as STEAM! This is where our work comes in!

Adding the arts to STEM to make STEAM is a relatively new idea in the conversation and holds promise as a key ingredient for addressing the lack of interest students have for STEM. Just as with STEM, the central idea is to move beyond traditional curricula with the disciplines siloed to purposefully and meaningfully cross disciplinary boundaries to solve complex and authentic problems (Bush & Cook, 2018). When considering reasons to add the *A*, the arts recognizes and shows appreciation for the role beauty, creativity, aesthetics, and emotion play in developing a solution to a problem (Bailey, 2016). Further, Smith and Paré (2016) contend that incorporating the arts addresses the affective connection for students to grasp difficult concepts. For example, in our own research (Cook & Bush, 2018), we discuss the transformative role empathy plays in a STEAM learning environment to engage students in developing solutions to problems in order to make the world a better place—providing the essential affective connection. Through our work with classroom teachers, instructional coaches, building and district administrators, and their K–5 students, we have witnessed firsthand how the integration of the arts provides a vehicle through which to engage more learners, specifically students who do not identify themselves as “being good” at mathematics or science (Ahn & Kwon, 2013; Bequette & Bequette, 2012; Wynn & Harris, 2012). Adding the arts, then, expands the STEM conversation from developing the nation’s next workforce to developing the nation’s next creative thinkers.

Teaching Takeaway

Adding the arts expands the STEM conversation from developing the nation’s next workforce to developing the nation’s next creative thinkers.



Core STEAM Idea

Equity, empathy, and experience build a foundation for successful STEAM education!

The Three Es: Equity, Empathy, Experience

In this section, join us in taking a closer look at how we conceptualize STEAM education—that is through equity, empathy, and experience, the Three Es! The order of the Three Es is intentional. Equity is first and foremost because when STEAM learning opportunities are created, the idea that each and every student should have access is nonnegotiable. Next comes empathy because we advocate that the empathy piece is the key ingredient to creating the most transformative STEAM learning experiences. The third *E*, experience, ties it all together articulating the key characteristics and benefits of effective STEAM instruction.

Equity

Figure 1.1 represents the three key ingredients needed to create equitable STEAM education infrastructures in classrooms, schools, and districts: (1) implement reform practices in mathematics and science teaching, (2) provide access to each and every student, and (3) explore meaningful and authentic problems through STEAM. Equitable STEAM education, through these three key ingredients can level the playing field for each and every learner. Each and every student should be able to see STEM careers such as scientist, mathematician, computer programmer, and engineer as a possible career option and also understand the role the arts has in these careers. We discuss the first two in this section.

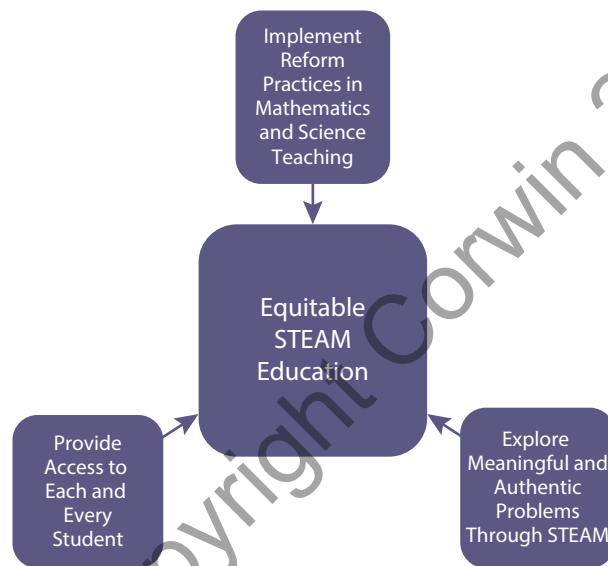


Figure 1.1
Three Key Ingredients
for an Equitable
STEAM Education

Start by considering the first ingredient, implementing reform teaching practices in mathematics and science education, such as those described in *Principles to Actions: Ensuring Mathematical Success for All* (NCTM, 2014) and *A Framework for K–12 Science Education* (National Research Council, 2012), which provides research-informed guidance on how to best teach mathematics and science for deep understanding. This is to be accomplished through strategies such as facilitating meaningful discourse, posing purposeful questions, supporting productive struggle, and engaging students in authentic scientific inquiry. Such reform teaching practices at their very core are designed to provide equitable access to high-quality mathematics and science education—maximizing each and every student’s learning potential.

While such reform teaching practices are at the core of our practice, our STEAM work has also led us to realize that reform teaching must extend beyond the boundaries of mathematics and science as single-subject areas. Rather, reform teaching practices *must* take place in the context of authentic integrated STEAM learning environments so that students see the purpose and experience firsthand that mathematics and science are how we make sense of the world. Through our lens on equitable access, we have learned that integrated STEAM instruction does the following:

- Provides a context for mathematics and science reform teaching practices to be realized
- Engages students in discourse, productive struggle, and authentic scientific inquiry
- Positions mathematics as an essential component to solving problems
- Explores authentic and meaningful problems
- Encourages each and every student to be interested and engaged in the STEM fields

The second ingredient necessitates a much-needed shift: All students need experiences in authentic integrated STEAM learning. All too often, authentic STEAM learning opportunities are presented as an enrichment class only for students who are perceived as advanced or gifted, a voluntary after-school program for those students already interested in STEM, or an optional summer camp. The script *must* be flipped. We argue that students who often have the least amount of access to authentic STEAM learning experience could benefit from it the most! A STEAM learning experience naturally lends itself to scaffolded instruction because the following occurs:

1. Inquiries are low floor, high ceiling.
2. Student strengths are showcased.
3. Students have a reason to care!

STEAM inquiries are open-ended and have multiple solution paths. Therefore, each and every student can enter and contribute to the inquiry (i.e., low floor), yet they are complex and students have the opportunity to provide solutions at various levels of sophistication (i.e., high ceiling; similar to low-threshold,

high-ceiling tasks in Huinker & Bill, 2017). Further, with the integration of multiple subject areas including the arts as well as the incorporation of the many soft skills students use in working together toward a common goal, each student can showcase their own strengths, as the experience is not one-dimensional. Finally, when students are engaged in solving authentic problems that interest them and in which there is a purpose, they care about it. This instantly leads to increased engagement and often fewer behavior challenges. For these reasons, it is not only a missed opportunity but inequitable to limit who has access to the most engaging and transformative STEAM learning experiences.

Teaching Takeaway

Students who struggle in single subjects are often the STEAM shining stars!



Pause and Reflect

What integrated STEAM learning opportunities are currently available at your school and/or district? Which students have access to these opportunities?

How might integrated STEAM learning address the needs of your classroom, school, and/or district?

Empathy

It can be simply stated: Not all STEAM inquiries are created equal! You might be wondering what we mean by this. Let us explain through two examples that address another key ingredient in equitable STEAM education: the importance of empathy. First, consider an **inquiry** centered on designing a nursery, courtyard, or garden for a school. This is a well-known and common integrated learning inquiry that tasks students to design a green space for their school. In this inquiry, students are engaged in each subject area of STEAM. Students use the mathematics of measurement to find the area, perimeter, and volume of the spaces and use computation with decimals to create a detailed budget plan. They explore the science of plants and their needs. Students engage in the engineering practices (e.g., using mathematics and computational thinking and constructing explanations and designing solutions) as they design the blueprint. Technology might be used to conduct research online or to design a blueprint using student-friendly design software. The arts are incorporated through the visual aesthetics. Through this work, students have the opportunity to apply the different subject areas while learning about designing a nursery, courtyard, or garden.

Now, let's take a look at another example of a STEAM inquiry. In this scenario, students begin by learning about a real challenge that some children face often in rural areas of the United States as well as around the world. Through student-led research, the class discovers that many households in a region close to them do not have consistent electricity. Students consider what it must be like to grow up in a home with no electricity and imagine how their own day-to-day routines would change drastically as a result. Students become passionate about helping other children their age and brainstorm ways to help—ultimately deciding to create and build battery- and solar-powered light sources to mail to homes in this neighboring region. To create this solution, students engage in the engineering practices (such as planning and carrying out investigations) as they try different solution paths and engage in testing and retesting their ideas. The knowledge of science (i.e., energy and electricity) and mathematics (i.e., angle measurements and budget computation) is needed to build and explain their designs. At the end, students decide that children their age would want visually aesthetically pleasing lights that reflected their interests, and they decorate them to a variety of tastes, incorporating the arts.

Now, let's take a minute to compare the garden inquiry with this Let There Be Light inquiry.

Inquiry:
Student-centered instruction that encourages investigation, exploration, discussion, and collaboration.

Teaching Takeaway

When students become passionate about solving a problem to help others, engagement soars!

How are these two inquiries similar?

How are these two inquiries different?

Have you implemented any inquiries in your classroom that share the characteristics of either the garden inquiry or the Let There Be Light inquiry?

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Consider your reflections from the table as we return to the idea that not all STEAM inquiries are created equal. We have found in our work that the most effective integrated STEAM inquiries include the following key characteristics:

1. Empathy
2. Undefined solution path
3. Creation of something for the greater good
4. Mathematics positioned as essential to make sense of the problem, not just as a tool

Let's begin with empathy, which we contend makes all the difference. When we design inquiries by first taking our students on a journey where they can feel what it is like to be in a certain situation or environment, the buy-in and passion students develop for solving the problem become inspiring, and this enthusiasm will carry with them throughout the duration of the inquiry. The Let There Be Light inquiry began with empathy. Second, because the most effective STEAM inquiries have undefined solution paths, this not only sets the stage for empathy but honors student creativity and multiple entry points into the inquiry as well, as with the Let There Be Light inquiry. Third, great STEAM inquiries often require students to create or develop a solution for the greater good of their school, their community, or the world. Finally, the best STEAM inquiries do not miss opportunities by overlooking the mathematics. Instead, the best STEAM inquiries use deep mathematical thinking to make sense of the problem rather than just as a tool.



Pause and Reflect

When have you used empathy in your curriculum? How did this affect students' level of engagement?

Name two aspects you still want to learn more about regarding empathy.

- 1.
- 2.



Try It Out!

As you've read this section, you've likely thought about how your existing curriculum could be adapted to better incorporate empathy. Stop now, and take what you've learned in this section to jot down three ideas for incorporating empathy into your existing curriculum. When you are finished, you are ready to move on!

- 1.
- 2.
- 3.

Experience

Now let us turn to the third E: experience. What unique experiences does integrated STEAM education provide? STEAM offers the unique opportunity for the following:

- Being in scenarios where perseverance is a necessity
- Addressing the so-what question
- Focusing on key mathematics and science content and practices
- Transcending the disciplines

In authentic STEAM inquiries, such as the Let There Be Light inquiry, students encounter a messy problem with an undefined solution path. Students are engaged in solving a problem where they must create the solution. As a result, students will reach failure points, and there will be many “course corrections” along the way, which help students build their perseverance skills.

Teaching Takeaway

With effective STEAM instruction, the so-what question is history!

STEAM addresses the so-what question in a powerful way—that is, Why am I learning this? When will I ever use this in real life? I know this now, but so what? With the most effective STEAM inquiries, a teacher will never hear these questions because students will already know the answers. The *why* and *so what* are the reason students are engaged in solving the problem in the first place. When students clearly understand why they are learning and see the purpose and value, amazing changes begin to happen.

Through innovative STEAM learning experiences, the following changes unfold:

1. Students become more passionate about truly understanding the concepts.
2. Engagement increases.
3. Classroom management challenges decrease.
4. The door to reaching each and every learner is opened.

Furthermore, a focus on key mathematics and science content and practices is also at the forefront of effective STEAM inquiries. In order for STEAM instruction to be effective, it is imperative to build foundational STEAM inquiries that start with alignment to key mathematics and science content and practice standards. When done intentionally, STEAM instruction can serve as a strategy for increasing students' mathematics and science achievement. Effective STEAM instruction is *not* about making and creating *nor* is it about arts and crafts. Rather, STEAM instruction *is* about providing students with needed learning opportunities to experience firsthand that key ideas in mathematics and science are used to solve real problems in our world. Only through such experiences can students begin to see how the different subject areas are connected to each other and used in tandem to generate thoughtful solutions. STEAM provides an avenue for students to explore how mathematics and science are used in different careers and how the components of engineering, integration of current technologies, and the arts (including aesthetics and creativity) all play a critical role in finding solutions to relevant, authentic, and meaningful problems.

Finally, effective STEAM inquiries not only integrate subject areas—they transcend them. While interdisciplinary learning occurs when content is the primary focus and a “synthesis of two or more disciplines” (Choi & Pak, 2006, p. 355) is at play, transdisciplinary learning in which the problem is the primary focus and the subject areas are explored more holistically requires “looking at the dynamics of the whole systems” (Choi & Pak, 2006, p. 355). In our work, we have seen firsthand the benefits of authentic problem solving that is afforded by transdisciplinary learning. We will continue to explore how STEAM inquiries can become transdisciplinary throughout this book.

Teaching Takeaway

Making without inquiry is not STEAM; it's just making!



Pause and Reflect

When was the last time you witnessed students persevering through a problem?

How do you address the so-what question in your classroom?

Name a time when you integrated mathematics into science instruction to make sense of a problem (not just as a tool). Why?

In your own words, define *interdisciplinary learning* and *transdisciplinary learning*.

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Try It Out!

As you've read this section, you've likely considered the learning experiences that take place in your classroom, school, and/or district. Stop now and do a SWOT analysis, which is where you consider strengths, weaknesses, opportunities, and threats to something you want to accomplish. Here, consider the following question: What are the strengths, weaknesses, opportunities, and threats to creating high-quality STEAM learning experiences for students in your classroom, school, or district? When you are finished, you are ready to move on!

Strengths	Weaknesses
Opportunities	Threats

Next Steps

Continue this STEAM journey with us as we explore the following questions in Chapter 2: What should be the focus of my STEAM teaching? Who should I involve? We will investigate strategies for targeting key mathematics and science learning outcomes while building in relevant technology and the arts to complement the engineering process. We will also consider potential partners with whom you will collaborate to support student learning in STEAM.

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