The Engineering Identity of Afterschool Educators

Emma Carey

When I first heard about joining science, technology, engineering, and math into the acronym STEM, it just sounded like a list to me. I thought, "That's nice, that multiple subjects are being taught together. But I still only really like science." I wondered why these topics were lumped together, and what exactly the connections were among the four subjects, beyond the vague connections of numbers and data. And, why, all of a sudden, did my interest in one subject suddenly mean I might be working with all of them?

In high school, biology drew me into the world of science. I wanted to learn about the animals of the world: why they did what they did, how they interacted with and influenced their habitats, and what the habitats themselves were like. I loved making observations, asking questions, and then trying different tools to answer those questions. I looked up to explorers like Jane Goodall, who sat with animals with a notebook for hours, simply recording what she saw. Observations and questions came naturally to me, just as they do for most young people.

As I dove deeper into science in college, the math inevitably snuck in. I wasn't excited about it, but if I wanted to learn about the age, health, or growth of a tree, the best methods were to measure the diameter and height or to count the leaves. I observed chickens in my animal behavior class and discovered that the most concrete way to describe their behavior was to count and calculate how much of the time they were performing one behavior versus another. Math became not just a list of equations, but a communi-

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cation tool, a way to shine a light on my fascinations and share them with others.

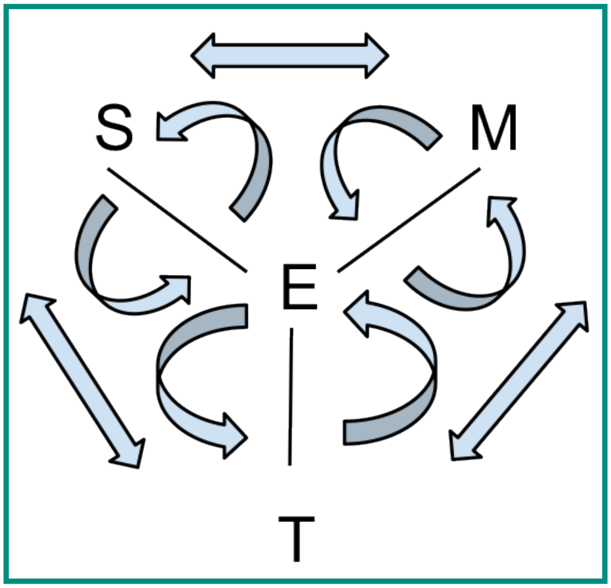
During the summers between college classes, I started teaching science at a small aquarium. Originally this job was a way to work closely with animals and to share my knowledge and my passion for nature with others. Soon, however, I discovered the joys of working with students and families. Guided by my graduate classes, I learned to encourage individuals to tune in to their own natural sense of wonder and then collect data to find their own answers to questions. I realized it was more fulfilling and effective to let youth in out-of-school time (OST) settings make their own observations, as opposed to trying to answer every question myself like a walking encyclopedia.

So, the science and the math, sure! I was on board. These two subjects were part of my interests and my life. But engineering and technology seemed a lot less familiar and accessible. Those two words were big and scary; they represented clunky computers and devices that had mysterious inner workings—things I didn't care to explore, dissect, or ask deep questions about, unlike the majestic creatures on Discovery Channel or in my backyard. I could leave the human-made mysteries to someone else, while I looked at the patterns of nature. Besides, engineering and technology sounded like the work of logistical-minded, calculating men, not wonder-loving young women like me. I didn't identify with engineering the way I did with science.

I started learning more about engineering and technology when I was learning to introduce educators to STEM. As it turns out, I've been engineering new technologies my whole life. EiE, the engineering design curriculum of the Boston Museum of Science, defines an engineer as "someone who uses [their] creativity and knowledge of math and science to design things that solve problems" (EiE, n. d.). The products engineers create are technologies. But technologies aren't just hard drives and software. Pencils, paper clips, and spoons are all technologies. Technologies don't even have to be physical objects; they can be systems or processes, such as alphabets or recipes. One way to define technology is "anything designed by humans to help solve a problem" (EiE, n. d.). When I learned these definitions, I realized that I used technologies all the time, and they didn't require a background in computers to understand. Problem solving and thinking outside the box were second nature to me while working with students. Thus, I had been engineering all along.

Engineering really tied the STEM acronym together for me. Science and math are the foundation for observing and making sense of the world, engineering is the identification of a problem, and technology is the solution designed to solve the problem. The acronym could be rearranged to MSET or to SMET, the acronym previously used by the National Science Foundation (Sanders, 2009), to reflect this order of operations. However, new technologies are helping to inform new advances in science, math, and the engineering process. Therefore, the best representation may be a nonlinear version that showcases all the connections, with engineering at the center, as shown in Figure 1.

Figure 1. Nonlinear Representation of STEM Connections



But I suppose STEM has the best ring to it.

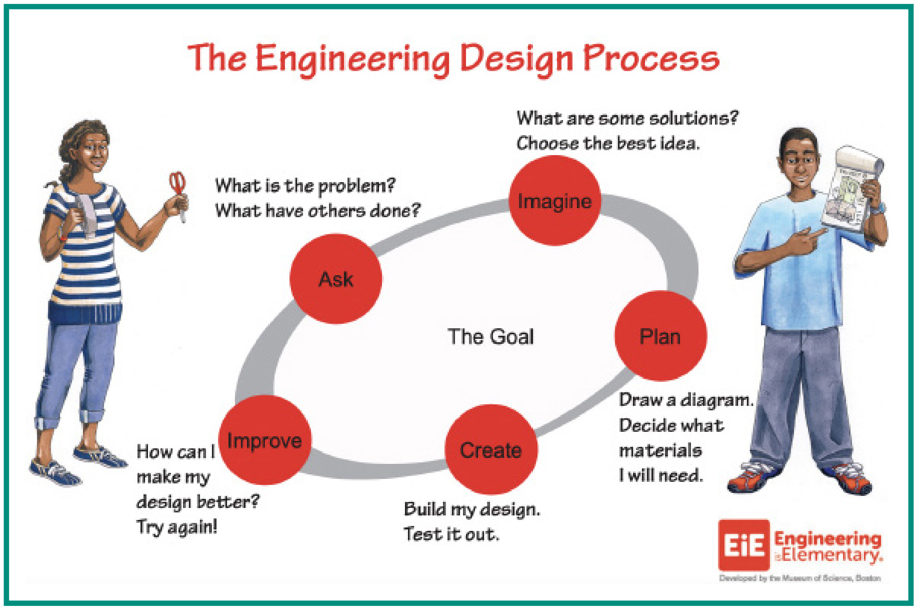
By learning about the best practices for teaching engineering, I realized I was already engineering, and so were most people I knew, including fellow OST educators. Anyone who has finagled a way to fix a broken button during a fashion emergency at a concert or wedding, fixed a crooked table by wedging something under an uneven leg, or created a chore chart and system to make sure that the house runs smoothly is an engineer. Software engineers and mechanical engineers are well-known titles, but there are also agricultural engineers who work on pollution and environmental issues, acoustical engineers who think about how to create the best sounds for music—and I believe educators are engineers as well: educational engineers.

Educational Engineer

There have been multiple uses of the term *educational engineer*. Some define an educational engineer as an educator who teaches engineering exclusively. Others define an educational engineer as a someone who works outside the classroom altogether, doing research and making decisions about curricula (Anderson, 1961; Charters, 1945; Rudinskiy et al., 2020). However, Beedeez (2022) defines educational engineering as "a structured process aimed at designing, adapting, or transforming a learning system in order to optimize the effectiveness of the training." When the term is defined this way, all educators are educational engineers. The term applies to any educator who observes youth, designs lessons around the needs of their students, and revises their plans throughout the teaching process. Just as there are scientific methods and practices, there are also engineering practices and an engineering design process, such as the one illustrated in Figure 2 (EiE, n.d.). Engineers ask questions to identify a problem, imagine solutions, make plans, create designs, and then improve them.

Educators carry out these same steps while preparing and teaching a lesson, as illustrated in Table 1 on the next page.

Figure 2. The Engineering Design Process



Source: EiE (n.d.). Reprinted with permission.

All educators design solutions to problems using the engineering design process. Afterschool educators in particular are flexible and frequently solve problems on the spot. I have seen many examples of the engineering design process taking place in afterschool programs in my coaching experiences in the ACRES (Afterschool Coaching for Reflective Educators in STEM) program, a free, nationally acclaimed coaching program that builds knowledge and skills so OST educators can confidently facilitate STEM experiences for youth (ACRES, n.d.).

Let's take, for example, an afterschool educator planning a simple engineering project with students. They have an initial image of how engaged they want the students to be, how much students will learn, and what students will take away from the activity. The educator *asks* about the best ways to accomplish this task. They know that many students have been talking about weather and wind in school, so they *imagine* an activity that complements this topic: building paper airplanes. They start to *plan*, thinking about how they will need materials for building the airplanes, a certain amount of time, a large space in which to test the planes, and good purposeful questions to prompt the students through the design process. They *create* the lesson plan, solving problems and *improving* along the way. They plan to carry out the building process in the classroom and determine that either the gym or the hallway would be a good location for testing airplane flying distances. They find out that the gym has been booked for the day, so they decide to test the airplanes in the hallway. They hope to give the students at least three different paper options to build with. Although only two types of paper are available, printer paper and construction paper, they find a few old posters that are about to be recycled. They plan to have 30 minutes for the activity, allowing 5 minutes for directions and student brainstorming, 15 for designing and building, and 10 minutes for testing

Table 1. Engineering Design Process in Education

Engineering Design Process	Educators' Process
Ask what needs to be done. Identify the challenge or problem. Make observations to determine the possibilities and constraints of the task.	Identify the problem: to provide quality programming for students in the time allotted with the resources at hand.
Imagine potential ways to solve the problem.	Think about options for carrying out the lesson, using your own or colleagues' previous experience.
Plan a solution to the problem.	Determine where the lesson will take place, how to set up the space, what materials to gather, and what questions to ask the students.
Create a solution to the problem.	Design a lesson plan (the technology), or adjust a previously created lesson plan, based on the time and resources available.
Improve, or redesign, based on new observations.	Make adjustments to the lesson plan based on the number of students who attend, changes in the setting, and what students already know.

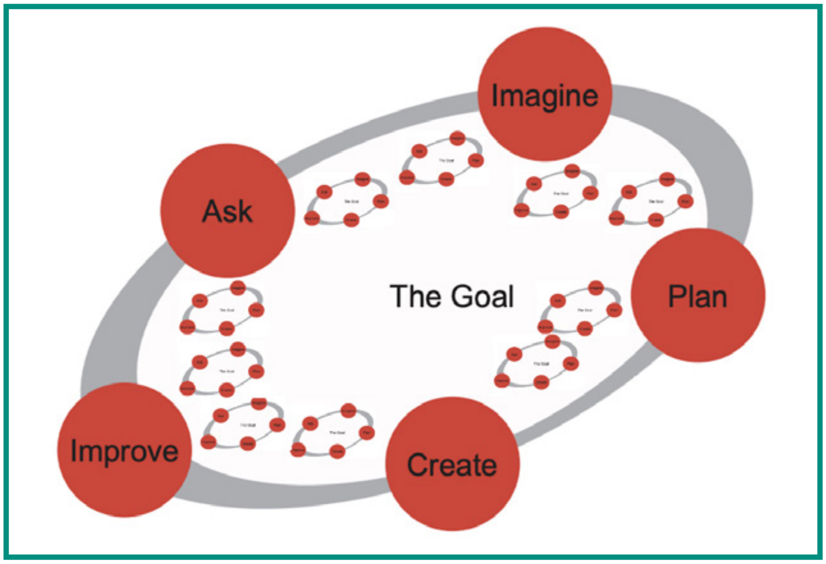
and then talking about the results. They come up with questions to prompt the students as they build, such as, "Why did you choose that type of paper?" "How do you think folding the plane in that direction will affect its ability to fly?" and "What do you notice about the flight pattern of your plane versus your classmate's plane?"

The engineering design process is neither linear nor circular. Engineers and educators both bounce around among the steps. Quite often in afterschool programs, things do not go as planned, and educators have to improvise and redesign activities. In ACRES, educators record videos of their interactions with students to reflect on their practice. Many times, when asked to explain their videos, educators share that changes occurred after they made their initial plan, and so the lesson had to be adapted.

In the paper plane example, when the time comes to implement the lesson, the educator is in the *create* phase and ready to go. However, they also find themselves going through small, fast-paced versions of the entire engineering design process as new problems arise. In response to new challenges, they ask new questions, make new plans, redesign, and improve on the fly. A fire drill at the end of the school day means the students arrive late, so the lesson time is shortened to 20 minutes. The educator shortens the introduction and presents the time constraint as an extra challenge for the students in their building process. There are more students than anticipated, and not enough materials, so the educator has the students work in pairs. They ask their planned questions as the students build, but some students are hesitant to answer. So the educator thinks about new follow-up questions to get the students to open up and think deeper, such as, "What materials do you wish you had?" Finally, as the group gets ready to test the planes' flying distance in the hallway, the educator realizes the school choir is practicing in the lobby, and the hallway is too loud. So the educator brings the students outside to the school courtyard to fly their planes.

Each of these little challenges requires the educator to work with an engineering mindset, solving problems and redesigning in the moment. Throughout the teaching process, educators use all the steps of the engineering design process. This process happens constantly in afterschool settings, not only in the initial process of planning and implementing a lesson plan, but also in the minute changes that need to occur in reaction to new situations arising. Figure 3 illustrates how mini-design processes are embedded in the larger process as educators adapt to changing circumstances.

Figure 3. Mini-Processes Within the Engineering Design Process



Note: Adapted from the EiE (n. d.) process

Building STEM Identities for Students and Educators

Current research has shown the importance of "demystifying STEM" in OST learning spaces to enable young people to strengthen their STEM identities (Cian et al., 2022; Edwards & King, 2023; Rahm & Moore, 2016). Building an identity means coming to see in oneself the characteristics of particular categories of people and developing a sense of how it feels to be that sort of person and to belong in those social spaces (Johnston, 2004, p. 23).

When educators foster familiarity and positive associations with engineering, technology, math, and science, they can inspire young people to see themselves in the world of STEM despite stereotypes and underrepresentation in STEM fields. Techniques to help students build awareness of their own STEM identities and visualize themselves in STEM careers include mapping STEM in students' everyday lives, looking for examples of STEM in photos and videos, and introducing students to STEM professionals (ACRES, n. d.). A STEM photo elicitation activity includes presenting a photo of a familiar scene, such as a construction site, a music classroom, or a garden, and asking students purposeful questions to encourage imagination and establish a problem-solving mindset: "What do you notice about the scene? What examples of science, technology, engineering, and math do you see in the scene? How might this scene be different if the picture was taken fifteen years from now?" Educators must empower students to feel connected to the scientific and engineering design processes so the students understand that they are problem solvers and that careers that involve solving problems are well aligned with their personal interests and goals (Pease et al., 2020). Engineering should be viewed not as a few specific majors or careers but as a *process* in which everyone engages daily. Educators can reinforce students' engineering identities by using language such as "Great problem solving!" and "You are an engineer!" while facilitating STEM activities.

These same strategies can be used to help educators identify the engineering in their own lives. Besides the everyday examples we highlight for students, educators can also be encouraged to see the engineering principles in the teaching practices that are already baked into their identities. They can come to see engineering as part of their identity, just as I have.

When I learned how much engineering pertains to my life, I found confidence in my ability to coach educators to facilitate engineering activities with their students. In the ACRES Facilitating Engineering Practices module, educators get hands-on with engineering. They observe and discuss technologies that don't require electricity or wi-fi signals, such as a spoon or an alphabet. They practice the engineering design process by building a tower out of notecards. In addition, they learn to empower one another by asking purposeful questions throughout the building process, saying, "You are thinking like an engineer!"—just as they will later when they implement these practices with their students.

When asked how they have solved a problem or engineered a solution in the past week, many ACRES educators talk about specific engineering activities they have done with their students. They identify science experiments, building projects, and computer science and math activities as examples. However, I have never heard an educator refer to the actual teaching process as an example of engineering. Similarly, in the ACRES Nurturing STEM Identity and Making Career Connections module, coaches ask educators to think about ways they engage in STEM in their everyday lives. In this case, educators usually go beyond classroom STEM activities to include cooking, fixing something around the house, or making measurements to rearrange furniture. But they still don't think about their teaching processes. By coaching them to think about lesson plans as technologies and to consider their pedagogical problem solving as an application of the engineering design process, I encourage educators to deepen their STEM identities and boost their confidence in their abilities to facilitate STEM activities with youth.

The Bigger Picture

In addition to boosting educators' confidence in facilitating STEM, shifting the language around education can change how educators are viewed. Engineers are considered to be respected intellectuals in our society. This perception creates a divide between those who are and those who aren't capital-E engineers. The term *educational engineer* was used as early as the 1920s. It is not an accident that the term has not caught on, as Charters (1945) explains:

> [C]urriculum planners carry on activities and have ideals that parallel those of engineering, but caution has always prevailed against the public use of the term [educational engineer]. Always present has been the fear that educators might be accused of borrowing the prestige of the engineer. (p. 29)

In other words, if society started to think of educators as engineers, we might have to uplift the status of educators.

By changing the language around education, we can empower educators to see themselves as STEM professionals—and possibly even begin to shift society's perceptions of educators at the same time. Educators are professionals in their field, just like other engineers. Could calling educators *educational engineers* create a cultural shift—one that sees educators as deserving of higher pay, more benefits, and more trust and respect? Language is powerful, and taking on a title or descriptor for yourself can be life changing. Author Rumaan Alam tells his classes, "If you write, you are a writer" (Skillshare, 2020). Similarly, if you solve problems, you are an engineer. If you are designing solutions for how to best teach your students, you are an educational engineer.

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