CHAPTER 1

Learn

Anyone who stops learning is old, whether at twenty or eighty. Anyone who keeps learning stays young.

—Henry Ford

Imagine a school where students build the classroom furniture, design outdoor landscapes, launch rockets, and create inventions to improve everyday life. What if school learning spaces were designed with comfortable corners for collaboration and areas to foster informal learning? What if students were given the opportunity to learn what they wanted to, pursuing their own interests within the school day? This is happening in elementary classrooms across the country! There is a shift occurring in education that has the potential to transform teaching and learning. With roots that date back to Dewey, Montessori, and Piaget, there is a movement for schools to return creativity and hands-on learning to the classroom, a belief that learning should be active and with students constructing their own knowledge.

While the accountability pressures on schools don't seem to be going away anytime soon, educators are embracing the idea of a school culture that emphasizes learning by doing. From the early 1900s through present day, student-centered learning has been a part of educational practice. President Barack Obama has taken notice of this renewed concept, stating, "I want us all to think about new and creative ways to engage young people in science and engineering, whether it's science festivals, robotics competitions, fairs that encourage young people to create and build and invent—to be makers of things, not just consumers of things" (Schulman, 2013). The events the President is suggesting are the types of opportunities that are beginning to occur in innovative schools across the country. The notion of citizens as makers, not consumers, connects to the mindset that is growing the Maker Movement and STEAM education.

There may be some resistance to this approach, especially with ongoing accountability pressures facing schools. With any change in practice comes excitement paired with anxiety and challenge mixed with uncertainty. Despite the push for rigorous content and standardized assessments, many schools are forging ahead with efforts to include STEAM and *making* into

their practices. STEAM Making is experimental and playful at times, but it connects critical academic content as well. As an instructional practice, STEAM Making represents the belief of new possibilities. These possibilities, presented to children, allow them to engage in the process of creating, designing, and pursuing learning that is interesting to them and has value outside of the school walls.

STEAM Making provides the opportunity for kids to get creative, collaborate, and engage in learning that is both challenging and fun. People outside of education are talking about these new ideas and the ways that they can infuse new life into schools and communities. The mayor of Pittsburgh recently opened his Maker Movement Roundtable by saying, "We are at the forefront of something pretty large, not only in this country but around the world." *U.S. News & World Report* summed it up best by saying, this initiative is "just getting started"! (**http://www.usnews.com/news/stem-solutions/articles/2014/02/13/gaining-steam-teaching-science-though-art**).

U.S. News & World Report

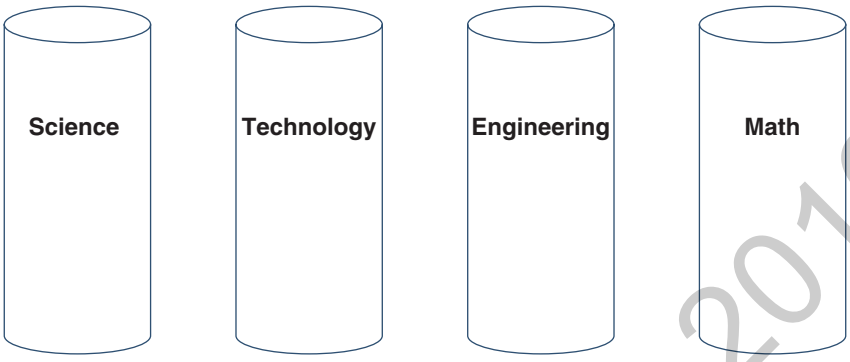
A 2008 study titled "Ready to Innovate" revealed that more and more companies are looking for skills in their new employees that involve creativity rather than achievement in core subjects alone. The study reported that companies want workers who can brainstorm, problem solve, collaborate creatively, and communicate new ideas. These aren't the skills of the 21st century. They are the skills of right now! Similarly, a collaboration of The Conference Board, Corporate Voices for Working Families, the Partnership for 21st Century Skills, and the Society for Human Resource Management (2006) compiled a report titled *Are They Really Ready to Work?* and stated, "Among the most important applied skills cited by employers are professionalism and work ethic, oral and written communications, teamwork and collaboration, and critical thinking and problem solving." We must ask ourselves if our current educational practices are preparing our graduates for this future.

HISTORY OF STEM

Many point to the Sputnik and the Space Race as the turning point for science education in the United States. Others connect the turning point to poor science and math scores by U.S. students, as highlighted by *A Nation at Risk* (U.S. National Commission on Excellence in Education, 1983). Now driven by business demands and the economy, STEM learning has been a prominent buzzword in education.

In the early 2000s, The National Science Foundation (NSF) coined the term STEM: learning based on the idea that science, technology, engineering, and math are interrelated and should be taught in an integrated way. Traditional teaching in these subjects is often presented as a silo model, with each being

taught in isolation, which prevents students from seeing the connections between the content learned in these areas.



My Two Cents

Throughout middle and high school, I struggled with math. It didn't matter which course, every single one was a challenge for me. I hated Algebra II. I barely passed geometry, and forget trigonometry. I remember staring blankly at equations and formulas and wondering to myself, "When am I ever going to use this again?" Since my math courses were entirely textbook driven, I never really saw math's connection to anything else. My teachers never gave any real-world examples. "Tonight, everyone will do the odd numbered problems" was a standard assignment.

Science was another story. While I wasn't convinced that dissecting sheep hearts was entirely my thing, I loved chemistry, astronomy, and earth science. These subjects led me to question things, experiment, wonder about possibilities, and think like a scientist. I had teachers who presented science as connected content, making meaningful connections to real life. These classes were tough, but the nature of discovery learning kept my attention.

I wonder what would have happened if my teachers had connected their subject matter together. Would I (and other students) have been more successful in math? Would an integrated approach have made more sense? Would the connections between math and science have led us to see the connections in other areas and to the world? While we can't live in a world of what-ifs, I believe that my high school grade point average would have inched a little higher had a STEM approach been implemented back in the '80s and '90s.

WHO NEEDS A JOB?

Integrated STEM learning is becoming a requirement to create the kind of workforce needed in the United States and across the globe. Schools are responding by creating STEM courses, after-school clubs, and summer camps. Others are revamping departments and restructuring curriculum to meet these demands. Some schools are even reinventing themselves as STEM-focused schools and academies.

On the main page of STEM Education News (**http://www.stemeducationnews.com**) this statistic jumps out: "By 2018 there will be 1.2 million job openings in science, technology, engineering, and math (STEM) fields. Due to a significant projected shortage of qualified applicants, many of these will go unfilled. The job market is demanding students increase their knowledge in STEM fields. In order to prepare students for this future, STEM education is building rapidly and transforming as it progresses."

STEM Education News

While some critics see STEM as a fad that will soon fade away, others believe this is a powerful vehicle to prepare our students for the global challenges in their future. As we know in education, though, things don't remain the same for very long. Once the importance for STEM was established, the idea began to transform.

ADDING THE *A*

Not long after STEM took hold, educators began altering the original concept. Obsessed with acronyms in education, STEM has morphed into STEM-X, TEAMS, STEAM, STEAMIE, and STREAM. At a recent conference, a colleague mentioned that one school was now using the term HAMSTER: Humanities, Art, Math, Science, Technology, Engineering, and Reading. Jesse Schell, CEO of video game design company Schell Games, warns educators of this very thing. "If you just start adding everything in there, then you are left with nothing. Nothing important" (personal communication, January 27, 2015). So, we need to ensure that we are making meaningful connections between subject areas in a way that prepares students for the real-world experiences that they will face once they leave the school setting.

In *The STEAM Journal*, Henriksen writes, "STEAM must become an essential paradigm for creative and artistically infused teaching and learning in the sciences" (2014, p. 1). I would argue that STEAM is a meaningful spin-off, especially in the elementary grades. The integration of arts into the STEM fields takes learning to a whole new level. The arts help to develop creativity, imagination, and collaboration (Sousa & Pilecki, 2013). Adding these components to STEM learning enhances the existing opportunities for critical

thinking, problem solving, and communication. By allowing for creativity and critical thinking, teaching and learning move away from convergent thinking to divergent thinking. But beware—this is hard for teachers! Fostering divergent thinking means that there is no longer one correct answer to every problem. It means that we need to look beyond the manual and the answer key and encourage kids to come up with their own questions and answers.

Henrisken (2014) also suggests that arts-based teaching leads to more motivated, engaged, and effective learning in STEM subjects. Adding the *A* to STEM doesn't mean just art. It is not an add-on that is merely decorative (Beckman, 2010). The arts should be an essential part of the process and could encompass drawing, painting, sculpting, music, movement, and video, just to name a few. In their book, *Invent to Learn* (2013), Sylvia Libow Martinez and Gary Stager state, "Combining the arts with STEAM means that children can express themselves in even more variations" (p. 55). The arts provide numerous creative pathways to learning. In their book *From STEM to STEAM*, Sousa & Pilecki (2013) share research-based reasons to integrate the arts:

- Engage the brain and develop cognitive growth
- Improve long-term memory
- Promote creativity
- Reduce stress

One of our goals should be to break down the barriers between creative subjects like art and music and more traditional subjects like science and math. This infusion of subjects will support learning for those that are creative AND logical-mathematical, unlike the silo model that isolates these topics. Developing creativity by integrating the arts makes a huge impact on student learning. The multisensory, hands-on nature that the arts can bring to STEM lessons helps students to connect to the content. Learning becomes more personal when students include an artistic component. An artistic representation of ideas and solutions is a valuable way to make learning personal. Infusing the arts may allow students to envision things in a different way.

LEFT BRAIN VERSUS RIGHT BRAIN

Are you left-brain or right-brain oriented? How about your students? Left brainers possess strengths in sequential thinking and critical details. These learners are logical, analytical, and driven by facts. For them, traditional teaching in science, technology, engineering, and math make sense. Those with inclinations toward the right brain are more creative in nature. They

don't think in a linear fashion. Some may be daydreamers, letting their imaginations run wild. This group is visual and artistic. STEM learning works just fine for left-brain learners, but often excludes those that are creative and artistic. STEAM embraces the arts and provides opportunities for both sides of the brain to engage. After all, shouldn't a well-rounded student develop both sides of the brain? Students can develop strategies and define patterns (left brain), and represent ideas spatially through color and design (right brain) all within a STEAM Making lesson.

WHAT EDUCATORS ARE SAYING

In a recent Google Hangout, participants pondered the shift from STEM to STEAM (**https://www.youtube.com/watch?v=GpaolpSxBZE&feature=youtu.be**).

Google Hangout

Educators from across the eastern United States talked about what makes STEAM different. These thought leaders from public and independent schools started by explaining the need for the *A*. They talked about the inclusion of the arts as a key element for bridging the learning that happens in traditional STEM courses and making it accessible to all learners. They stressed the importance of design thinking in K–12 education, urging others to talk with their students about problems and solutions and their ability to help someone or something by designing an innovative solution.

During the hangout three major themes emerged:

- The opportunity for creativity and originality
- The importance of perseverance through iterations
- The need to give and receive feedback in the process

While the focus of the discussion was STEAM education, these educators continued to stray away from using specific terms like STEM and STEAM to talk more about making in general. There is real overlap between the two. They described the work (no matter what name we give it: STEAM, making, hands-on learning, PBL [project-based learning]) as difficult. A STEAM teacher from a northeastern independent school explained that it takes patience and resilience. She shared what the students were making in her math class. In a spin-off of a traditional lesson on tessellations, her fifth- and sixth-grade students are now using laser cutters to create their own tessellations. The students are then using those manipulatives to teach their younger peers in kindergarten and first grade.

Schools are embracing the idea of STEAM education, with an emphasis on the *A*. This approach to instruction provides all types of learners with an

entry point into challenging content that connects with life beyond the school walls. The *A* is where STEAM and making intersect. It is at this crossroads where student engagement soars. It is the place where teachers and students have that "aha" moment; the aha that they are learning, when they think that all they are doing is "playing." While some makers may disagree and some scientists may balk at the idea of adding the artistic component to their left-brain thinking, these two practices connect in a number of ways, creating a promising alignment between STEAM and the Maker Movement.

On her blog User Generated Education (**https://usergeneratededucation.wordpress.com/2013/07/23/steam-and-maker-education-inclusive-engaging-self-differentiating**), Jackie Gerstein stated, "Maker education activities make for a beautiful integration of STEAM." In their classrooms, libraries, studios, and makerspaces, it is this "beautiful integration" that schools are discovering. STEAM supports right-brain thinking that includes imagining and risk taking, which are both critical tenets behind the Maker Movement.

User Generated Education

THE MAKER MOVEMENT

Whether it's remodeling and flipping houses, selling homemade goods on Etsy, or crafting items that were inspired by pins on Pinterest, people *are* making. Society is in a do-it-yourself era, which is only being fast-tracked through the use of technology. The Maker Movement has been sweeping across the nation in big cities, small communities, school systems, and online. This return to DIY (do-it-yourself), hands-on creating has spurred its own magazine, initiated makerspaces in libraries and community centers, and altered the way schools are looking at learning.

***Make* Magazine**

In 2005, the Maker Movement gained momentum when Dale Daugherty launched *Make* magazine (**http://makezine.com**). The magazine has connected people from a variety of disciplines and developed a common ground for making. The following year, the first Maker Faire© was held in San Francisco. A venue for crafters, tinkerers, and programmers, this event has continued each year, expanding to more and more cities. In the January 2014 edition of *The New Yorker*, Evgeny Morozov called Maker Faire© a "celebration of the DIY mind-set."

Maker Education Initiative

The celebration of making is spreading as organizations, foundations, and grassroots groups are popping up across the globe. The Maker Education Initiative (MEI) (**http://makered.org**) is one that works to build confidence, foster creativity, and spark interest in science, technology, engineering, math, and the arts, while creating opportunities in making. Their mission

is to provide resources to educators so that they are able to facilitate meaningful making experiences. MEI builds capacity within organizations so that young people can engage in making in both formal and informal environments. MEI seeks to equip communities so that kids and young adults from any background have access to making opportunities. The Maker Movement aligns with the need to increase STEAM education, as making embraces a similar philosophy of generating new ideas, engaging in hands-on/minds-on work, collaborating, and the integration of different fields.

Conversations are happening across the country to find meaningful ways to integrate STEAM and making into the daily work of educators and those who work with children and young adults. Formal conversations in offices and schools and informal conversations on Twitter and other social media are pushing this idea forward as well. (Check out #makered, #makerspaces, #makermovment, #STEAM, or #edtech on Twitter.) Elementary, middle, and high schools are creating unique spaces within their schools to develop STEAM learning and opportunities for students to engage in making. Libraries and community centers are welcoming artists, designers, and programmers into their buildings to provide hands-on activities not usually experienced in these spaces. Schools of higher education are paying attention too and are beginning to include STEM courses their teacher education programs. Some are embracing the concept even further, opening "makerspaces" on their campuses.

WHAT DOES MAKING LOOK LIKE IN SCHOOLS?

Find It! (Space)

Making can happen just about anywhere, but lots of schools are creating makerspaces or mobile making carts to facilitate these practices. Wherever the space—a room, the hallway, or outside—it needs to be accessible to everyone. Large or small, simple or complex, many schools are finding the library to be a good fit. Laura Fleming's book *Worlds of Making: Best Practices for Establishing a Makerspace for Your School* is part of the Corwin Connected Educators Series and is a great resource for those interested in starting a makerspace. As a library media specialist, she transformed the library at New Milford High School in New Jersey into an engaging space for her students.

STEAM Maker Storage

More STEAM Maker Storage

Learning Space

Learning Space

Fill It! (Materials)

With a large budget, you can buy all the latest machines and gadgets, but you can start making with little or no budget at all. Most schools already have the basics to start making: a couple of computers, tables and chairs, empty boxes, paper, scissors, glue. With parent and community donations, smaller items can be easily added, such as fabric scraps, buttons, needles, thread, old magazines, cardboard, plastic containers, and simple hand tools (hammer, screwdriver, etc.). With some funding, add sewing machines, hot glue guns, soldering irons, batteries, and motors.

A supply list to get you started is in Appendix E. (Also, read how Avonworth Elementary engaged parents and community members and stocked their makerspace in Chapter 2.)

Staff It! (People)

Providing access to making is important, but who is going to do all that work? Some schools have the ability to assign a full-time staff member to the makerspace or learning studio. Most schools will not be that fortunate. Building expertise among teachers is key, but this takes time. Providing professional development is one way to start. (Appendix B shows a sample professional development schedule that one school used to support teacher learning over the course of a year.)

Another way to build knowledge is through parents and community members. Can a parent who has a background in carpentry talk with students about safety in woodworking? Maybe a local architect could come in to provide a "lunch and learn" session with students to talk about their career? Could a group of moms who know how to knit or sew start a club for interested students? Tapping into parents as a resource is not only a free way to build expertise but also a way to build positive momentum for your program. If parents value this type of learning, they will help to promote the work that is happening at your school.

Six Reasons STEAM and Making Are Important

1. Everyone can be good at something.
2. They promote high levels of student engagement.
3. Learning opportunities are concrete, hands-on, and multisensory, meeting the needs of *all* learners.
4. Processes focus on the learning by doing, not merely the end product.
5. Open-ended tasks lead to higher-level questions.
6. Students (and teachers) learn that failure can be OK.

THE MINDSET

Embracing STEAM Making does require a certain mindset. There is a lot of discussion in education right now about the growth mindset. Carol Dweck (2006) defines the growth mindset as the power of believing you can improve. Some students (and teachers) have a fixed mindset, one that prevents them from growing and learning in the face of challenges. The belief that abilities can be nurtured and developed is clear inside classrooms and schools that embrace STEAM and making. In Dweck's 2014 TED Talk she emphasizes the importance of teaching our students that they *can* get smarter. It is that can-do attitude that needs to be present as we adjust our practices and integrate creativity into our classrooms.

A mindset to support STEAM Making can be defined within the four Ps:

- People
- Personalization
- Persistence
- Play

In schools where STEAM and making are growing, it is due to the **people**: teachers, principals, superintendents, and other school leaders who are fostering this mindset. STEAM and making thrive, not just because of the people leading it but because of the sharing and collaboration that happen among makers. When young people and adults are engaged in making, they share expertise and connect with others. This connection happens face to face in makerspaces but also online through a growing community of bloggers, "pinners," and "Twitterers."

STEAM and making are strategies that make sense for different types of learners. **Personalization** makes that possible. The hands-on nature of this

work lends itself to true student-centered learning. When students have a choice in what they are working on, engagement is high and students are focused. Enter a makerspace and watch students as they select materials or work on projects. Their personal interests drive their decision making. (You'll hear from students in Chapter 4 as they describe why personalization transformed their interest in school.) Traditional teaching and learning place teachers at the front of the room delivering content to students. When learning is made personal, the teacher can facilitate individual interests and foster the work initiated by children.

How often do you set your students up to fail? Probably not a question you've been asked before! Failure will be discussed more in Chapter 3, but it is an important component of **persistence**. Acquiring knowledge in STEAM Making comes through inquiry and exploration, as opposed to direct instruction or mastery learning. This takes time and effort.

Take a design challenge, for example. Students are given some materials, criteria for building, and time to work. The design process requires them to devise a plan—a plan that may or may not work. The plan may be revised or completely thrown out the window. The students might try several iterations of a model to meet the design criteria. This work can be frustrating for kids, especially for those who need instant gratification and validation. (Does this cover many of the kids that you know?) Developing a maker mindset means that teachers and students build qualities of perseverance and persistence in the face of challenges.

The last P is for **play**. STEAM learning and making are fun approaches to classroom instruction. Tasks tap into student curiosity and allow creativity to shine. Student makers tinker and explore with a variety of materials in a variety of spaces. STEAMers build and design in ways that challenge the mind and brighten the spirit. STEAM Makers combine to form a model of learning that is truly student centered and fun.

Things You Will Never Hear Coming From a Classroom That Embraces STEAM Making

Students

- "Why do I have to learn this?"
- "Am I ever going to use this again?"
- "Do I have to do this for homework?"
- "This is boring!"

Educators

- "My students aren't engaged."
- "He just won't pay attention."
- "Those students keep misbehaving."
- "This class isn't motivated to do anything!"

I'm not trying to say that *every* problem disappears when you engage students in STEAM Making, but many traditional problems do fade away. Keep in mind, they are replaced with new problems:

Students

- "Can't we do this project all day long?"
- "I need more materials to build my rocket."
- "Johnny won't let me use the soldering iron!"
- "I can't figure out how to add sounds to my animation."

Educators

- "My students want to learn how to _____ and I need some training."
- "I need a venue for my students to present their projects to the community."
- "We are inundated with recyclable materials and need more storage solutions."

IS IT PROJECT-BASED LEARNING?

Andrew Miller's 2014 post on Edutopia calls STEAM and making "a natural fit with project-based learning" (**http://www.edutopia.org/blog/pbl-and-steam-natural-fit-andrew-miller**).

Edutopia

All of these types of learning emphasize the process over the product. It is the actual learning that is important! When combining these ideas together the importance of integrated learning, real-world connections, and authentic work shine through.

If project-based learning is a collaborative and student-centered approach to learning, then it is a great fit with STEAM Making. It offers students the opportunity to engage in complex problem-solving tasks that often build on prior knowledge. These tasks require critical thinking and other skills needed for students to be successful in college, careers, and beyond.

Through PBL, students build competencies valuable for today's world. PBL allows students to engage in in-depth inquiry, asking questions, using resources, and developing answers. Projects are often focused on a driving question. Students can generate one that captures their interest and prompts exploration.

With students driving this learning, curiosity is nurtured and the voice of the student is honored. Led by student choice, PBL includes students in the assessment process as well. Learning to give and receive feedback on the quality of their work and making revisions are a critical part of PBL. Communicating about their learning beyond the teacher is encouraged in PBL. Sharing with the community or globally through technology can be incorporated in project-based learning.

Buck Institute for Education

The Buck Institute for Education (BIE) is a resource that provides teaching tools, curriculum materials, professional development courses, relevant research, and numerous student handouts to guide PBL in the classroom. Check out its website (**http://bie.org/about**).

At a recent Research Institute Summit, Will Richardson, author, speaker, and well-respected educational blogger, addressed the group about learning (**http://willrichardson.com**). He questioned all of the descriptors that often accompany the word learning: problem-based learning, inquiry-based learning, 21st century learning. Each has had their place in the cycle (and recycle) of educational practices. Richardson argues that it should boil down to simply—*learning*.

Will Richardson

WHY IS THIS IMPORTANT?

Twenty-first century students want active, relevant learning. They want to be connected to their peers, those in and out of school. They want to pursue their interests and have a choice in their learning. While this may be out of the comfort zone for some educators, there are many potential benefits to implementing this in the classroom. As we know, success beyond school requires more than basic knowledge and skills. Want students to understand content more deeply? Want them to retain what they've learned? Interested in seeing them build their confidence and solve complex problems? If we want to truly reach our students and help them to become thinkers, questioners, and innovators, then this is worth a shot.

BUT WHAT ABOUT STATE TESTING AND THE COMMON CORE?

Let's face it, if it's not PARCC (Partnership for Assessment of Readiness for College and Careers), Smarter Balanced or some assessment developed by our

state department, it will be something else. While it is tempting to let these distractions lead us to teach to the test and overwhelm our students with test prep workbooks, worksheets, and practice tests before the actual test, at some point we need to ask ourselves, What is really best for kids? Do we want to create a generation of good test takers? Do we want students who can click on a circle with proficiency? Or do we want students who can think for themselves, communicate with others, and successfully work with a team?

The Common Core State Standards' (CCSS) emphasis on real-world application of knowledge and skills, push for competencies in critical thinking, use of relevant technology and media, and focus on student collaboration fit well within the framework for STEAM education and the Maker Movement (see Table 1.1). The rigor and relevance that these newly adopted standards require can be addressed through hands-on/minds-on learning that happens in schools embracing STEAM Making. Students develop an in-depth content knowledge of the material they are learning about. They focus on the process of completing a task, not just the product. Engaging in problem-solving tasks, students learn how to reason and persevere when the answers are not right there in front of them. These experiences offer students the opportunity to build independence but also work collaboratively with others. The CCSS require students to investigate topics, analyze data, cite evidence, and present information. Isn't this what we want our graduates to do?

Since STEAM and making take an integrated approach to learning, students gain a more comprehensive understanding of topics and how the topics relate to the real world. The CCSS aren't the only standards that need to be considered, though. The Next Generation Science Standards released in 2013 also align with STEAM and making.

NEXT GENERATION SCIENCE STANDARDS

With the release of the Next Generation Science Standards (NGSS), this is a critical time to engage students in STEAM fields. "Science, engineering, and technology permeate nearly every facet of modern life, and they also hold the key to meeting many of humanity's most pressing current and future challenges" (National Research Council, 2013).

The NGSS include a framework for science learning that includes components of STEAM and making and was developed through a partnership between the National Research Council (NRC), National Science Teachers Association (NSTA), American Association for the Advancement of Science (AAAS), and Achieve (an educational, nonprofit reform organization). Twenty-six states collaborated with these partners to create them. These standards recommend that science be built around the following three major dimensions: (1) scientific and engineering practices, (2) crosscutting concepts, and (3) core areas.

Scientific and Engineering Practices

Scientists engage in certain practices as they investigate the world around them. Engineers also employ these practices as they design and build models. A strong foundation of both skills and knowledge are needed to develop these practices. With an emphasis on engineering, the NGSS stress the formulation of problems that can be solved through design. It is this type of learning that will clarify for students the relevance of science, technology, engineering and mathematics beyond school.

What does this look like in the classroom?

- Students asking questions as they plan and carrying out investigations
- Learners developing and using models to solve real problems
- Classrooms engaged in gathering, analyzing, and interpreting data as they construct explanations and design solutions
- Groups of students engaging in computational thinking and using evidence to build and defend an argument

Crosscutting Concepts

The NGSS define the crosscutting concepts as those that have application across all domains of science. These include patterns; cause and effect; scale, proportion, and quantity; systems; energy and matter; structure and function; and stability and change. Not only do some of these concepts have application in science and engineering, but they also have application in math, technology, and the arts.

Core Areas

The core areas, as defined by NGSS, are made up of physical science; life science; earth and space science; and engineering, technology, and application. These areas were selected because they are important across multiple disciplines. Within the general curriculum, these domains are taught over multiple grade levels at increasing levels of depth.

The three dimensions of the NGSS provide a framework for the K–12 standards in science and engineering, but combined with the CCSS, these also align with the four components of STEAM and the mindset for makers. The connection to the CCSS includes not only the Standards for Mathematical Practice but also the individual standards from within the English Language Arts Standards (reading, writing, speaking, and listening).

This is by no means a comprehensive analysis and alignment of the standards but rather intends to show the multiple connections between the two sets of standards and their alignment with the principles of STEAM and maker

TABLE 1.1 Correlations of Standards

NEXT GENERATION SCIENCE STANDARDS: SCIENTIFIC AND ENGINEERING PRACTICES	COMMON CORE STATE STANDARDS	ALIGNMENT WITH STEAM AND MAKER MINDSET
1. Asking questions (for science) and defining problems (for engineering)	**Speaking and Listening:** Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.	**Personalization**
2. Developing and using models	**Standards for Mathematical Practice:** Model with mathematics.	**Persistence**
3. Planning and carrying out investigations	**Standards for Mathematical Practice:** Look for and express regularity in repeated reasoning.	**Playful**
4. Analyzing and interpreting data	**Standards for Mathematical Practice:** Look for and make use of structure. **Standards for Mathematical Practice:** Reason abstractly and quantitatively.	**Persistence**
5. Using mathematics and computational thinking	**Standards for Mathematical Practice:** Make sense of problems and persevere in solving them. **Standards for Mathematical Practice:** Attend to precision.	**Persistence**
6. Constructing explanations (for science) and designing solutions (for engineering)	**Speaking and Listening:** Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience. **Standards for Mathematical Practice:** Construct viable arguments and critique the reasoning of others.	**Playful**
7. Engaging in argument from evidence	**Writing:** Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. **Reading:** Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence.	**People**
8. Obtaining, evaluating, and communicating information	**Writing:** Gather relevant information from multiple print and digital sources, assess the credibility and accuracy of each source, and integrate the information while avoiding plagiarism.	**People**

education. As you develop learning opportunities in STEAM and making in your school, you will certainly find additional connections to relevant standards.

WHAT DOES IT MEAN TO BE CREATIVE IN A STANDARDS-BASED SYSTEM?

Young children are instinctively creative: building with blocks, finger painting, using their imaginations, and exploring the world around them. STEAM education and the practice of making embraces this idea and enhances creativity beyond the general curriculum. In Yong Zhao's *World Class Learners*, the author discusses the fact that schools do not encourage creativity but instead "prepare good employees" (2012, p. 15). He advocates that education should never suppress curiosity and imagination. Taking that a step further, I would argue that schools should create opportunities to foster curious minds and pursue imagination, both in their students and teachers.

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Gregg Behr, executive director of The Grable Foundation, recently stated, "Today, new pioneers, gamers, roboticists, technologists, and designers are working alongside educators in and out of schools to inspire and provoke creativity and curiosity among children and youth in the region" (Coon, 2012). The freedom and flexibility to explore STEAM and making can be a challenge within a standards-based, accountability-driven educational system. It is a challenge that schools are taking along with community partners, libraries, parents, and corporations, positioning STEAM Making as a viable solution for positive educational change. This change is echoed by Sir Ken Robinson, ultimate supporter of creativity and innovation in schools.

In his 2006 TED Talk, Robinson implored educators to accept this changing paradigm and begin thinking about a new approach to teaching. His talk attained close to thirty-two million views on YouTube. He asserted that schools kill creativity and spoke about the uncertainty of the future. We know now that STEAM and the Maker Movement have forged ahead as a means to develop creativity and innovation in our students. Are you ready to accept this change and embrace the opportunities that come with STEAM Making in your classroom?

TRY IT CHECKLIST

Still not convinced that this idea is worth trying? If you can check off more than one thing on the checklist, then STEAM Making will bring value to your classroom.

Try It Checklist

I want my students to be able to

- ❑ Think critically about a topic, question, or problem
- ❑ Analyze those topics, questions, or problems
- ❑ Research information
- ❑ Direct their own learning
- ❑ Work successfully on a team
- ❑ Possess oral and written communication skills
- ❑ Work independently to complete a task
- ❑ Explain concepts thoroughly
- ❑ Apply learning to the real world
- ❑ Serve in leadership roles

EXPANDING YOUR THINKING

In what ways do I promote and honor both left-brain and right-brain thinking in my teaching?

How might STEAM and making fit into the learning happening in my classroom/school?

What do I need to integrate my subject area/classroom/content with others to ensure that students are breaking out of the silos and engaging in meaningful learning in science, technology, engineering, art, and math?