INTEGRATING STEM TEACHING AND LEARNING INTO THE K–2 CLASSROOM

Jo Anne Vasquez, Michael Comer, and Jen Gutierrez

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National Science Teaching Association

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FOREWORD

Integrating STEM Teaching and Learning Into the K–2 Classroom is a critically important contribution toward advancing STEM (science, technology, engineering, and mathematics) education for two overarching reasons: (1) It blazes a trail for early elementary classroom practitioners to reflect the latest thinking in STEM, and (2) it provides a means by which early elementary educators can meaningfully contribute to America's STEM movement.

The course for STEM education across the United States has been mapped in the report *Charting a Course for Success: America's Strategy for STEM Education*, released by the White House Office of Science and Technology Policy in December 2018. Readers and users of *Integrating STEM Teaching and Learning* by Jo Anne Vasquez, Michael Comer, and Jen Gutierrez can be confident of a close alignment between the broad consensus of the STEM education community as reflected in *Charting a Course* and the research-based insights and practical examples provided throughout this book. Common threads woven through both publications are the integration of STEM concepts and principles, the application of classroom experiences to students' lives, a priority on equal access to high-quality STEM education for all learners, the development of interpersonal skills including communication and perseverance, assessment to continuously improve outcomes, and other hallmarks of STEM education.

Today, STEM education has essentially eclipsed its own acronym to be an educational sea change from disciplinary silos toward solving transdisciplinary big questions and problems that converge multiple disciplines, making the enterprise far more interesting to learners. And it starts early, as Vasquez, Comer, and Gutierrez observe—"there is strong evidence that STEM learning can and does begin in early childhood classrooms" (p. 7). Thus, *Integrating STEM Teaching and Learning Into the K–2 Classroom* provides a superb roadmap.

–Jeff Weld
Executive director, Iowa Governor's STEM Advisory Council;
former senior policy advisor on STEM education,
White House Office of Science and Technology Policy

ABOUT THE AUTHORS

Jo Anne Vasquez is a recognized leader in science education. She is a past president of the National Science Teaching Association (NSTA) and the National Science Education Leadership Association and was a Presidential Appointee to the National Science Board, the governing board of the National Science Foundation, becoming the first and only K–12 educator to hold a seat on this prestigious board. She is currently the senior STEM (science, technology, engineering, and mathematics) consultant for Arizona State University's Office of Knowledge Enterprise Development.

Jo Anne's service and contributions to the advancement of science and STEM education at the local, state, and national levels have won her numerous awards: the 2014 National Science Education Leadership Award for Outstanding Leadership in Science Education, the 2013 National Science Board Public Service Award, and the 2006 Robert H. Carlton Award for Leadership in Science Education. She also received the Distinguished Service to Science Education Award, the Search for Excellence in Elementary Science Education and Supervision Award, and the New York Academy of Science's Willard Jacobson Award for major contributions to the field of science and STEM education. In addition, she was the 2004 National Association of Latino Elected and Appointed Officials honoree for her contributions to improving education.

Jo Anne has been involved with curriculum development for McGraw-Hill K–6 science, and she has facilitated STEM education professional learning sessions throughout the United States and in Thailand, China, Singapore, and the Philippines. A graduate of Northern Arizona University, she holds a bachelor of science degree in biology, a master's degree in early childhood education, and a PhD in curriculum and instruction.

Michael Comer began his educational career teaching middle school science in Dobbs Ferry, New York, and Riverside, Rhode Island, before joining the publisher Silver Burdett and Ginn (SBG) as the regional science/mathematics consultant. At SBG, he developed an expertise for providing rich and meaningful workshops that linked the facets of inquiry teaching with hands-on learning using manipulatives. He was an instructor at the Summer Science Seminar at Bridgewater State College in Bridgewater, Massachusetts, for more than 10 years, where he worked with teachers across the K–12 spectrum.

After the merger of SBG with Pearson in 1999, Michael was promoted to science curriculum specialist for STEM products, where he played a vital role in the development of new educational materials to meet changing market demands. In 2004, he joined Macmillan/McGraw-Hill as the national product manager for science and led the product development team in the creation of a brand-new science series, *Science: A Closer Look*, which quickly became a national bestseller. Michael transitioned from marketing to the editorial side of product development in 2013, when he became the editorial director for science and mathematics at Victory Productions in Worcester, Massachusetts, where he directed a team in content development and *Next Generation Science Standards* (*NGSS*) assessment item writing for major assessment providers and educational service organizations.

Michael, who has a BA in biology from American International College, has led many educational workshops on a range of topics in science and mathematics, helping educators embrace the new standards and infuse more hands-on, problem-based learning experiences into their classroom practices. Internationally, he has provided science professional development to teachers in Puerto Rico, St. Maarten, Bahrain, and the Kingdom of Saudi Arabia. His most recent work was to help produce a two-year professional development series for master science teachers in Thailand for the Institute for the Promotion of Science and Technology.

Jen Gutierrez began her educational career in Arizona in 1988, teaching first through fourth grades as well as K–2 multi-age classes. In 2006 she moved into the role of science curriculum specialist at the district level, and in 2014 she joined the Arizona Department of Education in the K–12 Standards Division as the K–12 STEM education specialist. Today she works as a STEM education consultant developing and delivering professional learning opportunities to support educators. She is a proud member of the *NGSS* writing team, including the Diversity & Equity team. She currently serves on the NSTA Board as division director of professional learning.

Jen is interested in three-dimensional teaching and learning, diversity and equity, and science and literacy, which are additional areas that she focuses on in her professional learning work. She did the keynote presentation, "Introduction to the *NGSS*," at the Shanghai International Forum on Science Literacy for Adolescents.

A graduate of Northern Arizona University, Jen holds a bachelor of science degree in journalism, a post-degree certification in elementary education, and an educational leadership–principal certification. She also has a master's degree in elementary education from Arizona State University.

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- Wendy Tucker, W. F. Killip Elementary School, Flagstaff, Arizona
- Lori Schmidt and Josh Porter, Broadmor Elementary School, Tempe, Arizona
- Joe Guiterrez, principal, Killip Elementary, Flagstaff, Arizona
- Allison Davis, kindergarten teacher, Chandler, Arizona

A special thanks goes to contributing author Joel Villegas for his work on Chapter 9.

These wonderful teachers and administrators truly helped this book come alive by providing real lessons and strategies to help teachers as they begin to implement STEM teaching and learning in their classrooms.

An additional special thanks to the countless K–2 teachers we have had the pleasure of working with over the years, who kept asking us to please write a book to support integrating STEM teaching and learning into the real world of a hectic and exciting elementary school day!

Lastly, we would like to acknowledge Jeff Weld, whose NSTA Press book, *Creating a STEM Culture for Teaching and Learning* (2017), provided some valuable foundational knowledge for our manuscript. Jeff also provided the report *Charting a Course for Success: America's Strategy for STEM Education* (Committee on STEM Education of the National Science and Technology Council, 2018). He is assistant director for STEM education at the U.S. Office of Science and Technology Policy.

INTRODUCTION

It's time to ramp up science, technology, engineering, and mathematics (STEM) in the K–2 classroom, according to the Community for Advancing Discovery Research in Education (CADRE). CADRE is a network for STEM education researchers funded by the National Science Foundation's Discovery Research preK–12 program. This new research suggests that high-quality STEM experiences in preK through grade 3 can offer a "critical foundation for learning about these disciplines in ways that facilitate later learning" (Sarama et al. 2018, p. 1).

In particular are the following benefits of early learning in science and math:

- It leads to social-emotional development and fewer challenging behaviors.
- It supports the development of a mind-set that includes curiosity, communication, persistence, and problem solving, among other habits.
- It contributes to gains in all other subjects by supporting literacy and language development and better reading comprehension and writing skills.
- It includes subjects that can engage students from varying backgrounds, including English language learners.

But delivering high-quality early STEM education requires expertise on the part of the teacher in scaffolding the lessons. Among the recommendations offered by Sarama et al. (2018):

- Encourage children to share and elaborate on their observations and ideas, even if they may be incorrect.
- Suggest additional investigations to test students' ideas.
- Provide all children with equal opportunities to participate in STEM experiences.
- Listen to the students and watch them as they play, explore, talk to one another, and engage in STEM activities, to get a sense of what they understand about STEM concepts.

This research lays the foundation for why high-quality STEM teaching and learning is critical in early childhood education; however, the researchers also point out that the teachers themselves need support as they learn how to facilitate STEM learning in their classrooms. Professional learning experiences are needed to cover how teachers can make connections between STEM topics and the everyday activities they are already doing with their students. STEM teaching and learning does not need to become one more add-on to the K–2 classroom. STEM learning should be a natural extension of what teachers are already teaching. It was with this in mind that we set out to write *Integrating STEM Teaching and Learning Into the K–2 Classroom*. We wanted to focus on how to naturally integrate STEM learning into K–2 classroom experiences.

New science standards across the country have keyed in on the idea that student learning is an integration of three central aspects of instruction: (1) tying together the knowledge of core concepts, (2) building fluency in the practices of scientists and engineers, and (3) fostering the ability to make connections across experiences. These things are key to developing long-term student understanding. The STEM lessons detailed throughout this book provide a relevant foundation to help you begin seeing science instruction through this lens as you expand and enhance your K–2 STEM teaching. Practicing K–2 teachers who have developed these exciting STEM lessons and units will take you on their STEM learning journey as they have implemented these experiences in their classrooms. The lessons are developed so that you can teach them in your classroom.

Before you begin your learning journey, we would like to share the following personal experience that author Jo Anne Vasquez had when she began her teaching career. Her story demonstrates that interdisciplinary teaching is not a new strategy for instruction, but is one that has been employed regularly by teachers looking to inspire their students. Many primary school teachers were providing these types of experiences for their students long before it was called STEM.

IT ALL STARTED WITH A CABBAGE

There was nothing unusual about this second-grade classroom. We had reading groups, math time, writing, science, social studies, music, and art—all the usual types of activities you would find in a K–2 classroom. I was so proud. I had survived my first year of teaching and this was the beginning of my second year. With feet now firmly planted on the ground, I knew the routine, and I smugly thought I had it all down. But little did I know that something was about to change the way I thought about teaching forever.

It was the second month into this new school year when the "Aha!" moment happened for me. I was about to get a lesson from my students on how important it is to make teaching and learning relevant for them. I would learn firsthand that using an integrated, interdisciplinary approach to teaching was the key to all of my students' learning. I was about to find that just delivering the content to my second graders was not enough. For these students to really understand and internalize that information, I would need to give them the ability to make connections to everything they were learning and provide opportunities to apply it in meaningful, personal, and grade-appropriate ways.

The Awakening!

The day started off like any other. Class had begun, and we were having our small reading group time at the back table. The story we were reading was about a farmer who had some rabbits that came into his garden and ate all his vegetables. He had carrots, tomatoes, radishes, and cabbages in his garden, and he was so proud because everything was just about ready to harvest. He was going to sell some of his vegetables and also make a wonderful meal for his family. We were talking about the story, and I was doing the usual types of activities that teachers do—checking for understanding, asking questions, calling on students to read certain passages—when all of a sudden a student said, "But teacher, I'm confused."

"Allison, what are you confused about?" I asked. Allison responded, "I've eaten carrots and tomatoes. I've seen radishes, but I've never seen a cabbage." When I questioned the others in the group, only one of the six had either seen or tasted a cabbage. This question alerted me to what I would later term "empty verbalization"—lots of me describing how a cabbage looked and what kinds of dishes you could make with it. All of which seemed to satisfy them for the time being. But who knew where that cabbage question would lead.

The next day I brought in a cabbage. We cut it apart. The children tasted it, felt it, and talked about how it looked and smelled. Of course they wanted to know how and where cabbages grew. And they asked, "Can we grow some?" Well, to make a very long journey a bit shorter, we decided to plant some seeds to watch them grow. We convinced our custodial staff to build some long trays that would hold soil for our plants. There was plenty of sunlight, as we had windows in the room. This became a true learning journey for all of us. We planned for cabbages, carrots, green beans, radishes, and tomatoes. The students learned to measure the plants, kept science logs to record their plants' growth, and checked out books from the library about the different kinds of plants and how they grew. We looked at the parts of the plants, and what began as a reading-group question became a several-months project.

But this story doesn't end with the garden. Many teachers actually do this type of project, so there is nothing unusual in this example. But what happened next was what today we might label a transdisciplinary experience—or more commonly thought of as problem- or project-based learning. When our garden plants were becoming mature enough to begin to harvest, the children wanted to share their plants with their parents. This became the transdisciplinary experience as our class set off to develop a meal, create a menu, and compose invitations to the parents.

Soon it was decided that the students needed help to cook the meal because they had chosen spaghetti. A few phone calls later, and a couple of eager parents agreed to assist. The student committee also asked our cafeteria staff if they could use the kitchen and would the staff join in to help cook the spaghetti. The students did butter their bread and mix their salad. At our feast, the children set the tables, served the plates of food, and spent time talking about what they had learned while growing their own salad. And best of all, Allison showed and described what she had learned about a cabbage. For if it had not been for Allison's question about the cabbage, this adventure would never have taken place.

Conclusion

We might venture to say that many of you reading this might be thinking that this example is no different from what you already do in your classroom. In many ways, interdisciplinary teaching is what preschool and primary teachers have been doing with their students. Most teachers of young students know instinctively that children learn best when they are active participants in the process. What many of you may have already been doing demonstrates the difference between just providing your students with *academic learning* and shifting the acquisition of knowledge to *intellectual learning*.

The differences are very obvious, according to Lilian Katz, professor emerita of early childhood education at the University of Illinois at Urbana–Champaign. Academic learning "is stuff that is clear like the alphabet, it has no logic, it just has to be memorized … and does have to be learned eventually," Katz states (see Pica et al. 2012). Intellectual learning "has to do with reasoning, hypothesizing, theorizing, and so forth, and that is the natural way of learning."

This research is not new. It seems that years ago in education we understood that students did learn best and retained the information longer when engaged in active learning in which they were predicting, hypothesizing, reasoning, applying, and describing what they were doing. Although it did not have the formal label of STEM education, interdisciplinary learning has been around for as long as students have been going to school. However, somewhere along the way, this active, intellectual learning became an afterthought. Today, we know that with the label of STEM, it has moved from the background to the foreground, and everyone wants to be on board the "STEM train."

Once, a second grader was asked, "What is mathematics?" and he responded, "It is something we do in the morning at school." We want our students to internalize what they are learning and be able to apply this new learning in many different ways. In other words, we want STEM teaching and learning to be part of the whole life of our students, and not just during school hours. During our journey together in this book looking at STEM teaching and learning in the K–2 classroom, we hope you will develop your own operational definition of what it means to be a STEM teacher. We hope you will learn some new strategies and gain some new ideas that you can use in your STEM lessons. We share what the research is saying about why STEM teaching is important in early childhood, with a focus on the K–2 classroom, and perhaps you will realize that you are already a STEM teacher, even if it all begins with a different kind of "cabbage question."

CHAPTER SUMMARIES

This book contains 10 chapters, with the following titles and summaries:

- **Chapter 1: Creating a Blueprint for Building Your K–2 STEM House.** What is STEM education in the K–2 classroom? How is it different from what primary teachers are already doing? How can you do it without adding more to an already full schedule or day? This chapter addresses these questions.
- **Chapter 2: Pioneering Into STEM Integration.** This chapter describes the different levels of STEM integration through the example of a second-grade STEM unit on early Americans and pioneers with English language arts as the driver.
- **Chapter 3: Unpacking the Integrated STEM Classroom.** In this chapter, we identify key elements found in an integrated STEM classroom, detail how they work together, and explore why these elements are critical to a successful student STEM learning experience.

- **Chapter 4: Tackling the Core Instructional Time.** This chapter takes into consideration how the STEM classroom can be used in concert with the core reading block to achieve the goals and objectives essential to all disciplines.
- **Chapter 5: Using the W.H.E.R.E. Model Template.** This chapter introduces the research-based W.H.E.R.E. model template. This template presents a clear and actionable process for curriculum developers and classroom teachers to follow as they develop their own 21st-century STEM experiences.
- **Chapter 6: Developing a STEM Unit With Math as the Driver—Straw Bridges.** The kindergarten STEM unit in this chapter describes how two partnering teachers created an integrated STEM unit using mathematics concepts as the primary instructional focus with the help of fifth graders in the school.
- **Chapter 7: Developing a STEM Unit With Engineering as the Driver—Baby Bear's Chair.** This chapter's kindergarten unit provides an example of an integrated STEM unit with an engineering and design concept as the primary instructional focus.
- **Chapter 8: Developing a STEM Unit With Science as the Driver—A Pond Habitat.** The second-grade unit in this chapter demonstrates how collaboration works in developing an integrated STEM unit using the help of community partners who work in STEM fields.
- **Chapter 9: Moving Students From Inquiry to Application—A Shade Structure.** This chapter's first-grade unit demonstrates how to develop a scenario from anchoring phenomena using a STEM unit that has science as the driver.
- **Chapter 10: Transforming Into a Successful STEM School.** This chapter describes how one district created a successful culture of STEM teaching and learning in its school through the commitment of various education partners working together toward a common goal.

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CHAPTER 6

Developing a STEM Unit With Math as the Driver—Straw Bridges

A square was sitting quietly
Outside his rectangular shack
When a triangle came down—Keerplunk!
"I must go to the hospital,"
Cried the wounded square,
So a passing rolling circle
Picked him up and took him there.

—Shel Silverstein, *A Light in the Attic* (1981)

Bridges, forces, compression, and tension—oh, my! Can this vocabulary be for kindergarten students? You bet! Come along as the "Straw Bridges" STEM (science, technology, engineering, and mathematics) unit unfolds based on the mathematical standards for the geometry concepts of identifying, describing, analyzing, comparing, creating, and composing shapes. Oh, yes. Squares, rectangles, circles, trapezoids, hexagons, cubes, cones, cylinders, and spheres are all found in the kindergarten mathematics standards. Two very creative teachers from Broadmor Elementary School in Tempe, Arizona—kindergarten teacher Lori Schmidt and fifth-grade partnering teacher Joshua (Josh) Porter—have developed and cotaught the following Straw Bridges STEM unit. The fifth-grade students become "learning buddies" to the kindergarteners and help them with their engineering projects.

At the beginning of any new curriculum planning adventure there is always brainstorming and reflection, and as you will read, this was not a canned STEM unit. Yes, Lori and Josh both had ideas about straw-building activities they had studied, but they took those ideas and developed their own integrated straw bridge STEM unit. Was it perfect the first time through? No, of course not. But like all great teachers, they monitored and adjusted their teaching to fit the students' needs. They also took notes about how to change or enhance the lessons to improve them for subsequent years.

Overview of the Straw Bridges STEM Unit

In Lori and Josh's words

We start the unit planning with a big idea or engineering task. We look at what we want students to have as an end product. In this unit, we started with the kindergarten math standards as the "driver." From there we identified the engineering properties as our "copilot," the technology needed to complete the project. We then decided that the science concepts, while necessary to understand the forces at work, would not be the focal point of the learning and therefore were the "back-seat passengers."

The big idea was to design and build a bridge using students' understandings of various shapes. This was the end product. But the necessary steps to complete the bridge design included allowing the students to tinker with their own ideas for design. Each successive lesson reinforced a concept necessary to build an effective bridge. Each lesson ended with examples of successes and failures in the design phase with reflections to help guide decisions for the next steps in the process.

Once the students have their own ideas for design, we introduce vocabulary as we go. Vocabulary is taught with kinesthetic movements so our English language learners and nonreaders can still demonstrate understanding.

DEVELOPING THE STRAW BRIDGE STEM UNIT

Lori and Josh had already decided on their unit's big idea, which was to have the students design and build a bridge using shapes that included circles, triangles, squares, rectangles, rhombuses, trapezoids, hexagons, cubes, cones, cylinders, and spheres. To get to this transdisciplinary task, they began with the first step in the W.H.E.R.E. planning template, which is to decide on the *what* (see Figure 6.1). What standards will be addressed? What content standards and big ideas will the students need to know and be able to do? What are the desired learning goals for this instruction?

Figure 6.1. The *W* section of the W.H.E.R.E. model

W	**What** are the desired results, including the big ideas, content standards, knowledge, and skills? • List the content standards and what the students will know and be able to do.	**Why** would the students care about this knowledge and these skills? • Craft the driving question that will lead to the development of the integrated tasks that provide for the application of the content, knowledge, and skills. • List the essential questions that can be answered as a result of the learning.

Having selected the *what* items in the first step, Lori and Josh began to think about the second part of the *W* guidepost—the *why*. Why would a student care about learning these concepts and skills? This can be hard to articulate beyond the response "Because it's in the standards." Being able to describe the *why* can help more clearly define the learning outcome. The *why* sets the direction of the instruction and helps craft the driving question that ties together the development of the integrated tasks to provide for the application of the content and skills. Without having a *why*, the learning can become directionless, getting mired in activities without having any real purpose or focus for the student. And while these activities may be fun and engaging experiences for children, they do not aid them in developing an understanding of the core ideas listed in the *what*.

In this example unit, the partnering teachers are from different grades. One of the overall goals is for the fifth graders to help the younger students with their constructions and learn how to cooperate with others. For the younger students, working with the older students gives them more in-depth talking time, as they need to describe their ideas and construction plans to their learning buddies. Various research studies support the positive effects that the role of mentor-mentee has on learning. Findings across many subjects have identified learning as an active process that is highly social and is enhanced by the intentional support provided by more knowledgeable individuals, whether they are peers, mentors, teachers, or experts in the field.

For the Straw Bridges STEM unit, the main drivers in its development were the kindergarten geometry standards from the Arizona State Standards (shown in Figure 6.2, p. 50).

Figure 6.2. The geometry standards for the Straw Bridges STEM unit

Geometry		
K.G.A. Identify and describe shapes	K.G.A.1	Describe objects in the environment using names of shapes, and describe the relative positions of these objects using terms such as *above*, *below*, *in front of*, and *next to*.
	K.G.A.2	Correctly name shapes regardless of their orientation or overall size (circle, triangle, square, rectangle, rhombus, trapezoid, hexagon, cube, cone, cylinder, and sphere).
	K.G.A.3	Identify shapes as two-dimensional (lying in a plane, flat) or three-dimensional (solid).
K.G.B. Analyze, compare, create, and compose shapes	K.G.B.4	Analyze and compare two-dimensional and three-dimensional shapes, in different sizes and orientation, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/corners), and other attributes (e.g., having sides of equal length).
	K.G.B.5	Model shapes in the world by building shapes from components (e.g., use sticks and clay balls) and drawing shapes.
	K.G.B.6	Use simple shapes to form composite shapes. For example, “Can you join these two triangles with full sides touching to make a rectangle?”

Source: Arizona Department of Education (2016).

In their description of the planning for this unit, Lori and Josh mentioned using the math standards as the “driver.” What did they mean? For every STEM unit there may be one discipline—or at the most two disciplines—driving the content standards that are the focus of instruction. In an integrated unit, the central focus for the learning cannot be all the standards covered. Too many different standards being introduced at one time can only serve to create confusion for the learners and interrupt their ability to concentrate on the acquisition of new knowledge and skills. As described in research cited in *STEM Integration in K–12 Education*,

> *Split attention—simultaneously dividing one's attention between competing sources of information—is cognitively demanding and can be a major obstacle to understanding and learning. The split-attention effect is evidenced by difficulties in storing and processing information that is physically separated.* (NRC 2014, p. 84)

Supporting standards can be woven into the learning experiences to provide opportunities for reinforcement and for extended practice of previously learned concepts. To help with this, we use the analogy of a car, first described in Chapter 5. In a four-passenger automobile, there is only one driver—the set of core standards that the instruction will focus on delivering. These cover the primary objectives for the unit and drive the learning forward. In your car, the front-seat passenger represents those standards that may be closely aligned to the driver and are helpful in navigating the instructional route. The front-seat passenger acts as the copilot to the core standards and influences the learning path necessary for greater student understanding. This can help provide context for the learning or make the experiences more rigorous and meaningful.

There may be passengers in the back seat—these are the tangential learning standards that could be tied to individual activities or the culminating product of the unit. For example, in the straw bridge unit, students may use a science text or leveled science readers for content acquisition, which can reflect English language arts (ELA) standards for analyzing informational text. The students will be practicing those ELA skills, but the primary instruction in the unit is not focused on the teaching of reading informational text. Or, students might connect their bridge project to issues that affect their community (whether it is the classroom, the school, or the broader neighborhood), which can tie to social studies standards, but the understanding of "communities" is not the focal point of the learning in the project. These are just tangential standards that help deepen the integrated learning experience beyond the STEM topics. These standards can be opportunities to reinforce previously taught concepts or a way to introduce an idea that will be explored at a future time.

The geometry standards are the driver or primary focus of instruction for the straw bridge unit. But as we all know, it is difficult to separate and focus on only a few standards. Therefore, the beauty of this unit is that it incorporates other standards from both science and ELA. Once you identify the main content driver that you want to stress and really focus the learning around, there also will be other supporting standards (passengers) to consider. This is part of your decision-making process as you begin to think about your STEM unit scenario and start to develop the W.H.E.R.E. template. Integrated STEM units are just that: integrated with more than one standard to help reach the answer to the unit's driving question and to facilitate the completion of the transdisciplinary task.

BRAINSTORMING THE STRAW BRIDGE STEM UNIT

Lori and Josh also realized that they could incorporate standard K-PS2-1, Motion and Stability: Forces and Interactions (see Figure 6.3, p. 52), from the *Next Generation Science Standards* (*NGSS*; NGSS Lead States 2013). This standard was comprehensive enough for them to develop their ideas of having the students begin to understand pushes and pulls as they examined different shapes found in bridges. The students were introduced to local bridge builders who used sophisticated terms such as *compression*, *tension*, *structure*, *support*, and *trusses* in describing the images they shared of how they build bridges. Students' use of this vocabulary evolved naturally as they tried to articulate their understandings of why some shapes were more successful than others. All of this

Figure 6.3. *NGSS* performance expectation for K-PS2-1

<table>
<tr><td colspan="3">K-PS2-1 Motion and Stability: Forces and Interactions</td></tr>
<tr><td colspan="3">Students who demonstrate understanding can:
K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.
[Clarification Statement: Examples of pushes or pulls could include a string attached to an object being pulled, a person pushing an object, a person stopping a rolling ball, and two objects colliding and pushing on each other.]
[Assessment Boundary: Assessment is limited to different relative strengths or different directions, but not both at the same time. Assessment does not include non-contact pushes or pulls such as those produced by magnets.]</td></tr>
<tr><td colspan="3">The performance expectation above was developed using the following elements from A Framework for K–12 Science Education (NRC 2012):</td></tr>
<tr><th>SCIENCE AND ENGINEERING PRACTICES</th><th>DISCIPLINARY CORE IDEAS</th><th>CROSSCUTTING CONCEPTS</th></tr>
<tr><td>Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in K–2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.
• With guidance, plan and conduct an investigation in collaboration with peers.
- -
Connections to the Nature of Science

Scientific Investigations Use a Variety of Methods
• Scientists use different ways to study the world.</td><td>PS2.A: Forces and Motion
• Pushes and pulls can have different strengths and directions.
• Pushing or pulling on an object can change the speed or direction of its motion and can start or stop it.
PS2.B: Types of Interactions
• When objects touch or collide, they push on one another and can change motion.
PS3.C: Relationship Between Energy and Forces
• A bigger push or pull makes things speed up or slow down more quickly. (secondary)</td><td>Cause and Effect
• Simple tests can be designed to gather evidence to support or refute student ideas about causes.</td></tr>
</table>

Source: NGSS Lead States (2013).

led up to the development of their transdisciplinary engineering design task, which was to have the student groups build a bridge that could hold at least five or more books without collapsing.

In the primary grades, we find it difficult to separate and focus on only one of the engineering design standards. It is not that the individual learning objectives of the standards cannot be isolated, but it is difficult to cut short the learning experience when student excitement is at a peak. What fun is it to talk about a problem or generate a solution without the opportunity to try building it? How do you foster persistence, experimentation, and self-reflection if you don't allow time for solution improvements? For these reasons, in this primary-grade unit the supporting content includes all of the engineering design standards (ETS) in addition to the science. There are of course other content standards, but in this unit, the understandings about geometric shapes will be held at the forefront of the planning and will act as the driver. The engineering design standards will play the role of the front-seat passenger.

Math is the main driver for this STEM unit, but as you can see, the engineering design standards and science are essential secondary or supporting standards (Figure 6.3). These are the passengers in the STEM car. As Lori and Josh were designing this STEM unit, part of their decision-making process was to think about the unit holistically, and looking at the standards that needed to be taught and those that could be used to reinforce previously covered standards helped with the development. As the overall idea for the STEM unit takes shape, it then becomes a process of thinking about what interesting or relevant scenario can be crafted, which will lead to the development of the driving question. In this case, the students were learning about different types of bridges, they were using their straws to construct different geometric shapes, they were learning a rich variety of core ideas and new vocabulary words, and they were building comfort in collaborating and communicating with each other (see Figure 6.4 and Figure 6.5, p. 54).

Figure 6.4. Students creating their shape pieces prior to bridge construction

Figure 6.5. Students beginning construction of the straw bridge

Having decided upon the *what* and the *why*, it was now time to put it all together with an engaging scenario that would draw from the essential questions and bring together all the content for the students. This scenario or storyline helps the students become active participants in the learning, while the driving question communicates the purpose for learning by providing a real-world context that the students can relate to. This scenario gives students the opportunity to apply their key understandings in their transdisciplinary task.

THE SCENARIO

In developing this Straw Bridges STEM unit, the teachers aimed to give students experiences with seeing shapes, creating models, drawing shapes, and composing composite shapes found in the real world (math standards K.G.B.5 and K.G.B.6). The students described the shapes by talking about those found in different types of bridges. From there, Lori and Josh decided to bring this home with the following scenario:

> *There was a very heavy rainstorm, and it washed out the bridge to the town. The families needed to return to their homes. They loaded up trucks with supplies but*

> *they needed a bridge to cross the river in order to get home. You are part of an engineering design team that has been asked to construct a new, strong bridge. But first your design team will need to build and test models to decide on the best and strongest design for this new bridge.*

Now, with a scenario in mind and the content standards in place, it was time to create the driving question that would tie together the development of the integrated tasks: "How can we design and build a bridge out of straws with tension and compression so that the bridge does not collapse when tested?" (see Figure 6.6).

Figure 6.6. Students testing their straw bridge construction

The completed *W* section of the W.H.E.R.E. model (see Figure 6.7, p. 56) provides a description of the planning for the *what* and the *why*. It describes the key drivers for the instruction in the unit.

Figure 6.7. *W* section of the W.H.E.R.E. template for the Straw Bridges unit

W	**What** The students will develop an understanding of different geometric shapes through hands-on experiences where they use these shapes to design and build a bridge. ***Main standard (drivers)*** K.G.A. Identify and describe shapes. 1. Describe objects in the environment using names of shapes, and describe their position using terms such as above, below, besides, in front of, behind, and next to. 2. Correctly name shapes, regardless of their orientation or overall size (e.g., circle, rhombus, trapezoid, hexagon, cube, cone, cylinder, and sphere). ***Secondary standards (passengers)*** *Engineering Design* ETS1.A. Defining and Delimiting Engineering Problems ETS1.B. Developing Possible Solutions ETS1.C. Optimizing the Design Solution *Science* Motion and Stability K-PS2-1. Plan and conduct an investigation to compare the effects of different directions of pushes and pulls on the motion of an object. *English Language Arts* K.RL.1. With prompting and support, ask and answer questions about key details in a text. K.SL.5. Add drawings or other visual displays to descriptions as desired to provide additional detail. K.SL.6. Speak audibly and express thoughts, feelings, and ideas clearly.
W	**Why** Students can better understand the attributes of different shapes when they are used to solve a problem. The bridge problem offers a variety of successful design solutions. ***Driving question*** How can we design and build a bridge out of straws with tension and compression (push and pull) so that the bridge does not collapse when tested? ***Essential questions*** *Mathematics* • What geometric shapes can be used to construct an effective bridge? • What total geometric design used to construct our bridge is most effective? • What are the attributes of the different shapes that were used to construct the bridge?

Continued

Figure 6.7 (*continued*)

W	***Essential questions*** (*continued*) *Engineering Design* • What observations and questions need to be answered before you can solve the problem? • How can the engineering design process be used to find a solution to your design problem? • How will drawing a picture or creating a blueprint of the design help with the construction of the bridge? • Is there more than one design that will provide the best solution for the strongest bridge structure? *Science* • How can we best describe how much force we can place on our bridge? • What simple tests can be used to determine the stability of the bridge? *English Language Arts* • Using the design of the bridge, how can you explain, in your own words, the two types of forces—compression and tension (push and pull)?

Special Thanks

A special thanks to Broadmor Elementary teachers Lori K. Schmidt and Joshua Porter for opening up their classrooms and sharing the Straw Bridges STEM unit. Following is a bit more about these two dynamite teachers and how they became interested in implementing STEM instruction in their classrooms.

In Lori's words

How did I become interested in STEM? My daughter is a senior at Northeastern University and majoring in mechanical engineering. My interest in STEM started with my daughter being in a field dominated by males. It is very important to expose all children to STEM, but getting girls excited about these particular fields has been a focus of mine since I started teaching in the 1980s. If I can give my students opportunities to explore STEM and develop a passion in this area, then hopefully they will seek out jobs in a STEM field.

In kindergarten, the vocabulary learned, the critical thinking processes used, and the development of fine motor skills are enhanced greatly by using STEM. In order to compete in this global world/economy,

Continued

(*continued*)

we need to start teaching STEM when the children are very young, and that is why I started in kindergarten. STEM is fun for me to teach and for my students to learn.

In Josh's words

I have been teaching in the Tempe School District for 10 years and teaching in some capacity for 17 years. I believe in teaching to the head, the hands, and the heart to help develop well-rounded citizens. I focus on integrating English language arts, technology, kinesthetic learning, art, and STEM to create a diverse and innovative classroom. I think that teaching techniques that are a benefit to some will benefit all.

I first began teaching in a STEM-oriented way because conventional math and science classes were not focusing on science and engineering concepts. My goal is to develop STEM units based on real-life scenarios that give children context for the importance of science, technology, engineering, and math. The key to collaboration comes from children of different ages discussing, inquiring, designing, experimenting, and reflecting. I believe that learning by itself isn't fun, but that "fun" is the byproduct of high-quality learning experiences!

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