Where's Spot?

Finding STEM Opportunities for Young Children in Moments of Dramatic Tension

By Elisabeth McClure, Lisa Guernsey, and Peggy Ashbrook

It is a Friday morning at Liberty Elementary School in Baltimore, and a group of first-graders are hard at work at a science center on the second floor. Christian, a little boy in a navy sweater and baggy jeans, grabs a bin filled with plastic tracks for building bridges and roadways. "Hey Malaya, come on!" he says to a classmate in a yellow shirt and pigtails. "Let's build a track!" Christian works quickly, laying out each piece, rifling through the bin to find exactly the sizes he's looking for.

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Malaya plops down on her knees next to him to help. Christian talks as he works and describes his growing structure, which now includes a series of inclined tracks. The two students work side by side, until they are finally ready to attach their two sections together.

Once they do so, they step back to admire their work. Christian picks up a little plastic ball and holds it in suspension just above the tallest ramp in their track structure. "Let's test this out!" Malaya looks at Christian, and they smile.

At that moment, both kids are electric with anticipation, nearly holding their breath. What is going to happen? Will the ball make it all the way down the track to the edge of the carpet? Will it get stuck along the way? How fast will it go?

It is a moment of drama among many moments of drama that play out every day at Liberty, where this science center declares itself with a big banner that says "Idea Lab" and the shelves are lined with science books, jars of beads and balls, cartons of colored pencils, cardboard boxes, and bins filled with interlocking plastic blocks. Four desktop computers are open for playing Mine-

ILLUSTRATIONS BY LIZA FLORES

craft, rugs are spread out on the floor for building with blocks, and tables offer laptops for drawing shapes and diagrams using computer graphics.

This school has embraced a truth that is difficult for many people to see: the potential for integrated science, technology, engineering, and math (STEM) learning really is all around us. And the moments of intense drama these children experience when they test out a new design are the engines that drive STEM practices; it's what keeps scientists, programmers, engineers, and mathematicians up at night, wanting to try *just one more* possible solution to a problem. STEM is full to the brim with drama.

The converse is also true: dramatic storytelling is full to the brim with STEM. While we rarely recognize it, STEM processes are at the heart of the narratives we love. Stop for a moment and consider your favorite novel or movie. What's at the heart of the story? What makes you turn the page or keep watching? At their core, narratives are almost always about the dramatic tension created when someone faces a challenge or barrier and attempts some strategy to overcome it. A great mystery hangs in this implicit question, "Will it work?"—whether it's asked about a social interaction or a physical experiment—and this tension is the heart of STEM.

When our team started its research on early STEM learning in 2015, this focus on drama and storytelling was not the expected result. Our project, funded by the National Science Foundation, was designed to help researchers, educators, and policymakers gain more insight into how they could work together to infuse STEM experiences into early childhood. The outcome was a major report, called *STEM Starts Early*,* that included not only a suite of recommendations for the adults involved in children's learning, but also a new language for communicating about the importance of STEM opportunities for little kids. This rethinking of early STEM learning led us to a few important insights.

STEM Is Full of Drama

STEM experimentation—when it's conducted without the use of "leading questions" or plot "spoilers" given away beforehand—should draw you to the edge of your seat, like you're watching the last three minutes of your home team's final game. STEM learning should feel like the unfolding drama of a well-told story; it should be near-impossible to walk away. So when you're doing your STEM instruction, highlight that drama and be prepared to support children through the highs and lows of their unfolding STEM stories.

Back at Liberty Elementary, Christian drops the ball gently on the plastic track. It rolls along just as he had hoped. "Look, Malaya! It works!" he squeals. Their relief is tangible. But so is their excitement to try another design. Christian scurries back to the bin, saying, "Let's get the other track so we can keep working!" Malaya springs to action by putting one of the blocks in a new position. "Ooh, let's try this, lay it this way," she says.

In fact, according to recent research, these STEM lessons and habits of mind—habits such as design and systems thinking, reasoning, collaboration and communication, exploration, and persistence—have significant positive effects on other learning domains. For example, it probably comes as no surprise that high-quality, facilitated early science experiences, like the ones kids experience at Liberty, support the development of children's executive function skills, like cognitive control, especially the ability to reflectively revise predictions based on their observations.[1]

High-quality early math education may also have similar benefits for encouraging executive function development, including skills like working memory (the ability to hold something in mind while working on a task), inhibition (the ability to control one's impulses), cognitive flexibility (the ability to adapt one's strategies when encountering new information or situations), and sustained attention.[2] In fact, early math instruction, when done well, is a great example of cross-domain effects more generally: it can lead to higher scores in early language and literacy, including the ability to express one's knowledge and understand others' spoken words;[3] and, remarkably, preschool math skills predict later academic achievement more consistently than early reading or attention skills.[4]

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That's because the competencies and habits young children form when they experience STEM education are integral to how children learn to learn.[5] As children go through their lives and learn new things, they braid all those individual skills or "strands" together into braided "skills ropes." Then they can use these ropes to do all the complex things they must do to function well in school and in life: solve problems, work with others, formulate and express their ideas, and learn from their mistakes. Children can use STEM skills, which are especially adaptable and strong, in weaving *many* different kinds of skills ropes. When kids have strong STEM strands, they can use them for all kinds of things, both practical and academic, that they will need to be able to do throughout their lives.[6]

In other words, when children become immersed in the unfolding drama of STEM experiences and are supported by their teachers, they learn skills that apply not only to their own understanding of science, technology, engineering, and math concepts, but to many other aspects of their lives. Fostering their engagement in these intense narratives encourages them to persist in their explorations and to embrace challenges—and even failures—as the building of dramatic tension that can propel them forward, both in their current project and in life.

Drama Is Full of STEM

Once you identify the hidden drama in STEM experimentation, it becomes much easier to incorporate it into your existing lessons in the classroom. For example, when you're doing your literacy instruction, highlight the STEM experimentation evident in the narrative.

This takes a little preparation. It is not unusual in Ms. Shaw's class, for example, to hear young children use engineering

*To read the full report, visit www.joanganzcooneycenter.org/publication/stem-starts-early.

words like "troubleshoot" or "test" or "run it" as they go through trial and error, creating new designs and products. They are words the students learned at the beginning of the school year, when Ms. Shaw taught a lesson on "prototypes." She explained that "design thinking" is about flexibility and the openness to use observations and tests to inform how they make improvements over time. Once children have this understanding of flexible design thinking, you can use it to help them identify STEM practices in the dramas that naturally unfold all around them, even in the books you read together.

This is possible even with very young children, because even simple stories rely on experimentation for dramatic tension. For example, in the lift-the-flap book *Where's Spot?*, a mother dog is looking for her hiding puppy, Spot. As we turn the pages, the children are invited to search for him by lifting one flap per page:

> *Is he in the box? No!* (Turn the page.)
>
> *Is he in the closet? No! Where could he be? Let's keep looking!* (Turn the page.)

You might not have realized it before, but this story, at its core, is a beautiful enactment of STEM practices. Each time the children turn the page and discover a new place to look…

- …the tension builds as they **form a prediction** *(Maybe Spot is in the closet!)*,
- …they lift the flap (the closet door) to **test their prediction**,
- …they are surprised to **observe** that their prediction is not supported *(A monkey in the closet?! Silly monkey!)*, and
- …they **troubleshoot and revise** their prediction as they turn the page *(Maybe Spot is in the cupboard!)*.

Pausing during reading and asking open-ended questions or prompts opens the door for children's comments, claims, and wonderings, and research suggests that giving them this opportunity to exercise their mutually reinforcing STEM, language, and literacy knowledge and skills can lead to improvement across all three areas.[7] These STEM practices are already present all around them; our job is to make those processes explicit for children. Show children they are already doing science all the time, and they will begin seeing themselves as scientists.

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In fact, many children's books (picture books too!) even include core ideas that are in the Next Generation Science Standards (NGSS), which were released in 2013 to integrate content with science practices across disciplines and instructional levels.* Consider, for example, the character of Ned in Remy Charlip's classic, *Fortunately*. He receives a letter (paper and writing tools are a form of technology) inviting him to a birthday party that turns out to be so far away (math, and NGSS Practice 5: Using Mathematics and Computational Thinking), he needs to borrow an airplane to get there (technology). His journey has ups and downs, problems to solve, and an element of chance. Every page is an opportunity for children to notice an A-B pattern (math, and NGSS Practice 4: Analyzing and Interpreting Data), make a claim about what might happen next (science and engineering, and NGSS Practice 7: Engaging in Argument from Evidence), and describe what they would do to overcome difficulties such as falling into shark-infested water (math—e.g., How fast would they have to swim to escape?—and NGSS Practice 5: Using Mathematics and Computational Thinking) or digging a tunnel through the earth to escape tigers (engineering and technology—e.g., using a miner's pickaxe—and NGSS Practice 6: Constructing Explanations and Designing Solutions).

These more dramatic challenges mirror children's challenges with riding a trike with a broken wheel, running away from a friend, and digging holes in the sandbox, and they demonstrate that scientific inquiry is a messy, creative endeavor (not a series of ordered steps we follow) when it's experienced in the world. These STEM-infused dramas appear routinely in works of fiction and nonfiction. Some additional book examples are included in the sidebar to the right, involving "characters" as diverse as a chicken and a young library patron.

Highlighting STEM in books like these demonstrates for children the opportunities for STEM learning they can experience outside of school, whether that's on the way to a birthday party, at a library, or at the grocery store. In fact, books (and newer technologies too) play an important role in bridging school learning with other learning spaces, like homes, local libraries, recreation centers, churches, and museums. Developmental experts like to call these out-of-school learning spaces "charging stations," where children can power up their learning to keep their STEM batteries active at all times.[8]

*For more on these standards, visit www.bit.ly/2stnt2R.

Strengthening these charging networks is especially important for students like those at Liberty, a high-poverty public school in northwest Baltimore, where more than 85 percent of the students qualify for free or reduced-price lunch. Children in these neighborhoods tend to live where there are few, if any, charging stations outside of school. So when an educator gives a child a book to take home, when a class takes a field trip into nature or to a science museum, and when a teacher uses or suggests well-designed apps (like Bedtime Math†) to engage parents in their children's learning, they are actively strengthening the network of charging stations for children. And, just like with learning a language, the immersion children experience with a strong charging network leads to STEM fluency, both in and out of school.

No Special Equipment Necessary

Some might think that giving young children rich STEM experiences will require schools to buy a bunch of new equipment and materials. And others might think that only some young children will be receptive to engaging in STEM explorations. But once educators begin to recognize the drama and narrative of STEM, doors can open to new possibilities, even in low-income schools such as Liberty, whose students are doing better than most Baltimore students on the state's tests of mathematics and English language arts.[9]

That success is not a result of programs targeted toward a select few; instead, it's the result of a shared investment and belief in the capacity of young learners, and an unspoken understanding about the power of drama. In treating explicit STEM lessons like dramatically unfolding stories, and by using moments of drama, trial and error, and other science practices in non-STEM subjects, educators can help students think like engineers and scientists. Such approaches can then give children the confidence and skills they need to redefine "failure" as the plot twist that inspires the next chapter of their story. There are few better life skills we can give them.

As Ms. Shaw reflected while watching Malaya and Christian work diligently to fix their track: "This is so much easier as a learning experience than having them come in and sit at the carpet having to be still," she says. "I think 21st-century learning looks like this." ☐

(Endnotes on page 39)

†To learn more about Bedtime Math, visit www.bedtimemath.org/apps.

Highlighting STEM during Storytime

The children's book *Rosie's Walk*, by Pat Hutchins, is a story full of STEM, as tension rises each time a fox sneakily approaches Rosie, a hen. For example, the title page picture of the entire farm introduces the concepts of mapping and viewing landscapes from different perspectives (math, and NGSS Practice 2: Developing and Using Models), and positional words ("across," "over," "under") in the text guide readers through the landscape.

Questions involving science and math concepts arise as the drama of Rosie's walk unfolds: When they jump onto the haystack, why does the fox sink down into the hay but Rosie the hen does not? How does loosening the rope holding the flour sack make it fall on the fox? Why does the wagon begin to roll when the fox jumps into it? Why do the bees fly after the fox and not after Rosie? This book can inspire hands-on classroom investigations into mapping a familiar area, building structures, using pulleys, rolling objects, and understanding the behavior of insects. The plot of the story gives children an anchor for their questions and increases the drama in the classroom experiments they can conduct as they explore these new learning areas.

Even books about everyday activities children experience, like going to the corner store or to the library, include important STEM elements. For example, while reading the book *Lola at the Library*, by Anna McQuinn and Rosalind Beardshaw, students engage with concepts of calendars, time, and distance, and see how the use of technology and engineering design apply in ordinary situations. By asking open-ended questions and highlighting inferences in the book, teachers can help children apply the information they gather to help make predictions and find solutions as Lola goes through her day.

At the beginning, we learn that Tuesdays are library days—Will Lola go to the library today? (math, and NGSS Practice 1: Asking Questions)—and that the library opens at 9 o'clock (math). Then, Lola uses an engineered design solution for transport (her backpack) as she gathers all the materials needed for a trip to the library and walks there (engineering, and NGSS Practice 6: Designing Solutions). Another familiar engineered design solution for transport, a stroller, is also pictured. Children can describe what kind of technology their library uses after reading that the librarian "buzzes" books through "the machine." Lola sings as part of the library's program for children (adding art to STEM). And drama? Which books will Lola choose to check out? Children can point to evidence for what kind of books they think Lola might pick out.

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Endnotes

1. Jess Gropen et al., "The Importance of Executive Function in Early Science Education," *Child Development Perspectives* 5 (2011): 298–304. Executive function is the ability to supervise and control one's own emotions and thinking. See Douglas H. Clements, Julie Sarama, and Carrie Germeroth, "Learning Executive Function and Early Mathematics: Directions of Causal Relations," *Early Childhood Research Quarterly* 36 (2016): 79–90.

2. Clements, Sarama, and Germeroth, "Learning Executive Function and Early Mathematics."

3. Julie Sarama et al., "The Impacts of an Early Mathematics Curriculum on Oral Language and Literacy," *Early Childhood Research Quarterly* 27 (2012): 489–502.

4. Greg J. Duncan et al., "School Readiness and Later Achievement," *Developmental Psychology* 43 (2007): 1428–1446.

5. Greg J. Duncan and Katherine Magnuson, "The Nature and Impact of Early Achievement Skills, Attention Skills, and Behavior Problems," in *Whither Opportunity? Rising Inequality, Schools, and Children's Life Chances*, ed. Greg J. Duncan and Richard J. Murnane (New York: Russell Sage Foundation, 2011), 47–69.

6. Elisabeth R. McClure et al., *STEM Starts Early: Grounding Science, Technology, Engineering, and Math Education in Early Childhood* (New York: Joan Ganz Cooney Center at Sesame Workshop, 2017).

7. McClure et al., *STEM Starts Early*.

8. McClure et al., *STEM Starts Early*.

9. "Liberty Elementary, School No. 64: School Profile – Spring 2017 Update," Baltimore City Public Schools, accessed June 9, 2017, www.baltimorecityschools.org/cms/lib/MD01001351/Centricity/domain/8783/schoolprofiles/2017_18/20170517_Liberty_School_Profile.pdf.

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