Reassessing Recess

Recognizing and supporting scientific and engineering practices in play

By Alison Riley Miller and Martha Eshoo

In the preschool play yard, several children crouch in the sand near a rain-soaked tarp. Two children dig a small hole by twisting a piece of wood in the sand. Others gather and a discussion ensues about how to fill the hole with water and keep it from draining. One child runs to fetch something to "put in the bottom" of the hole while two others announce they will fill pots with water to dump inside it. A fourth child suggests, "if we just pull this tarp over, we can spill the water off of it into the hole." Their teacher stands nearby, quietly observing as the children try various means to fill the hole with water and keep it from draining. The teacher slides an additional metal pot and large spoon into the area where the children are at work, and then steps back again, observing.

What can we learn about the development of scientific and engineering practices through careful observation of children's play? Rather than focus on a specific content lesson, this article focuses on preschool learners and the scientific and engineering practices they use when they are given opportunities for self-directed or "free play" in a rich learning environment. Free play remains a core component of most preschool programs, but time for this kind of exploratory play has been reduced in many classrooms as teachers report greater curricular demands related to Common Core math and literacy.

SCIENCE IN PLAY

Children are natural scientists and engineers (Gopnik 2012). They are curious about the world around them and eagerly explore, test, and manipulate their surroundings. They do this through play, and while play has long been recognized as a cornerstone of learning, some studies suggest that children's scientific process skills may be better developed through exploratory and self-directed play than through direct instruction (Bonawitz et al. 2011). This constructivist approach is based on the idea that science learning is best supported when children are given rich opportunities for exploration and hands-on experiences and when these activities include appropriate scaffolding from a knowledgeable adult (Trundle and Saçkes 2012; Vygotsky 1978).

The release of the *Next Generation Science Standards* (NGSS) has generated renewed focus on fostering STEM in preschool and early elementary learning environments and has given teachers the language to articulate how STEM emerges during play. However, much of the conversation has focused on structured activities, curricula, and science centers in the classroom (Saçkes, Trundle, Bell, and O'Connell 2011). But what about all of the time that preschoolers spend engaged in self-directed free play? Can teachers harness this time as an opportunity to deepen children's exposure to and engagement with STEM? We think so!

We suggest that by learning to observe and identify the eight practices defined in the *NGSS* (NGSS Lead States 2013) preschool teachers can support three-dimensional learning even during free play. They can do this by attending to the physical environment and materials available for play, by helping children articulate when they are engaging in science and engineering, and by drawing connections between children's play and the crosscutting concepts and disciplinary core ideas explored in the curriculum.

Using the K–2 grade band summaries from Appendix F of the *NGSS* (Table 1), we set out to explore how scientific and engineering practices could be identified during preschooler's self-directed play. We aimed to characterize the teacher's role in both setting up the physical environment—what we call "setting the stage"—and in helping children to articulate the scientific nature of their play—what we call "narrating the scene." The result is a framework for identifying if and how preschool children are using the scientific and engineering practices—the "process skills" of science—in their play. By using this framework, it is our fervent hope that early childhood teachers might feel more comfortable both "setting the stage" for science learning and for helping children articulate the science practices and concepts they engage with in their play.

SETTING THE STAGE

In one classroom, a preschool teacher was reading a book about trees to her students at story time. Shortly after that, when the children went outside to play. Their teacher walked around the play yard placing buckets, shovels, spoons, and other tools in a variety of locations. When the teacher observed two children using spoons to dig between the roots of a tree nearby to see if it was "drinking water," she slid an additional scoop and another bucket beside them, using these "loose parts" to set the stage so the children had additional materials for their investigation. When one of those children stated that she couldn't find water because the roots "go too far down," their teacher responded with, "That's a good observation! I wonder why the roots grow so far down?" A conversation followed in which the children hypothesized about why the tree roots go so deep. Were they finding water deep down? Were they going deep to keep the tree from falling over? Children explore science concepts through play when teachers take on the role of stage-setters and mindful observers, carefully avoiding interactions that might disrupt children's investigations while providing appropriate scaffolding in the form of questions or narration. (Bonawitz et al. 2011; Weldemariam 2014).

Over the course of our research, we observed preschoolers engaging with emergent forms of multiple scientific and engineering practices (Table 2) and we noted the ways in which teachers set the stage (providing natural materials, space, and undisrupted time) for children's inquiry as they explored their environment, posed questions, and solved problems. Sometimes preschoolers articulate what they are doing as they engage with emergent practices of science and engineering but, more often, we've seen that young children learn by building an embodied knowledge of their environment (e.g., understanding that it is easier to move *down* a slope than *up*; understanding how to stabilize a seesaw by using their bodies to provide counterbalance on each side of the fulcrum).

Many preschool and early elementary teachers feel intimidated by the idea of teaching STEM, reporting that they do not have the depth of content knowledge or the experience to teach science and engineering confidently. However, we found that when teachers were provided with a description

TABLE 1

Adapted from *NGSS* Appendix F: Scientific and engineering practices, K–2 grade band.

SCIENTIFIC AND ENGINEERING PRACTICES	OBSERVED EXAMPLES	SETTING THE STAGE
1. Asking questions (for science) and defining problems (for engineering)	Students notice that sand is heavier after rain. They ask a teacher why it is heavier.	The play space is designed so that children can access sand and dirt in varied weather and states.
2. Developing and using models	Students use string and a wooden box to make an imaginary sailboat. They run out of string and decide to use a stick instead to "raise the sail."	Heuristic play encourages the use of "loose parts" or familiar and non-directive materials. Children will often turn to creative solutions and further investigations when they have few "assigned" toys (e.g., dump truck, dinosaur, replica fruit) to access.
3. Planning and carrying out investigations	Students explore a "seesaw" they made by placing a board over a fallen log. One child tries to push his end down while another child is standing on the opposite end. The first child can't force her end down until the second child steps off. The second child exclaims, "Woah! I didn't see that coming!" as her end of the seesaw pops up behind her after he steps off (see Figure 2).	Materials for building large structures are available and stored to encourage children's investigation and use. The ramps, stumps, and long beams that children use to create a ramp or a seesaw are part of their everyday play.
4. Analyzing and Interpreting Data	A student discovers that sand pours out of one container more quickly because it has more holes through which the sand can fall. The same student notices that some sand is too damp to pour out of the can. She samples sand from several different locations around her.	Materials available to students for their investigations includes cups, buckets, and other familiar items. A sieve, colander, or flour dredger can be used to shake and filter sand.
5. Using mathematics and computational thinking	Students pull each other in a sled using a rope. They note that when there are lots of children in the sled, it is harder to pull them. When a few students get out to help pull, they observe that the string gets very tight, but the sled still won't move. One student exclaims, "It is too heavy!"	Weather and seasonal shifts offer a changing landscape for play. The use of a sled in snow, ice, and water offers children the opportunity to count and to consider size, weight, and force.
6a. Constructing explanations (science)	Students experiment with running up and down a hill. They note that they can run faster downhill. They propose that one should "run harder" when going uphill.	Hills, berms, and uneven ground allow for rich exploration. The opportunity to go up an incline and then down offers students a chance to experience and build an embodied understanding of momentum.
6b. Designing solutions (engineering)	Students are walking on a "bridge" made with planks on stools when they realize it's not "smooth" because the stools are uneven. One child suggests they take the planks off to fix this. They do so and this child leads the group, putting the bridge back together.	The materials available for play are varied in size, shape, and texture so that children have opportunities to design solutions (collaboratively or independently) for problems they identify.
7. Engaging in argument from evidence	Students are digging in the dirt when one holds up something shiny and declares, "I found a crystal!" A second student counters, "No it's not. It's just mica." The first student responds, "Well, mica is a kind of crystal." The second student examines the rock, peeling off layers before concluding, "Yep. This is mica."	A variety of materials are accessible to children throughout the day. They are given flexibility and agency over where and how they use these materials so that they can collect data, construct explanations from evidence, and engage in argument with their peers.
8. Obtaining, evaluating and communicating information	Students describe their garden and explain that it's time to put the plants "to bed" because they're done growing but they will grow again next year.	Gardens offer experiences in stability and change as well as opportunities where children can examine plant parts. In the preschool program, children notice shifting seasons and make observations related to those changes.

for each of the eight scientific and engineering practices (Table 2) along with researcher-observed examples of what those practices might look like in a play-based environment, preschool teachers began articulating other instances of the eight practices beyond the examples given by researchers. In fact, teachers began having deep conversations with one another around children's engagement with scientific and engineering practices and connecting those practices to disciplinary core ideas and crosscutting concepts the children explored. Teachers also started stage-setting more intentionally with natural materials and loose parts to foster that engagement. Had it rained the day before? Teachers set out buckets, scoops, and shovels for exploring puddles and wet sand. Were the trees beginning to lose their leaves? Teachers set out baskets for collecting and paper and crayons to make leaf rubbings and ask about the colors and patterns children see. The examples that follow represent just some of the emergent scientific and engineering practices that we observed across multiple preschool play spaces.

In the first of these, a researcher observed two children rolling rocks back and forth along a table. The children observed and articulated how the differently shaped sides of the rocks caused them to roll differently. One child then compared rolling those differently shaped rocks to rolling a ball. In this example, the children *carried out an investigation* (Practice 3), collected *data* in the form of multiple observations as they rolled the rocks, and *interpreted* and *communicated* their observations to each other (Practices 4 and 8), finally comparing properties of the rocks with those of a ball. In this instance, the nearby teacher quietly watched, offering encouragement by her presence and occasional narration like, "You are observing those rocks carefully," or "You noticed that rock was rolling differently than the other. I wonder why?" In her narration, the teacher opted to encourage continued conversation and articulation of ideas rather than offering a pat explanation to students. This type of scaffolding encourages students to construct and revise their own scientific ideas.

In a second example, a child collected leaves from around the play yard during the autumn season. She then sorted them by color (observing the properties of those leaves) and noted differences in the quantities of leaves in each pile (Practice 5: Using mathematics and computational thinking) using terms like *more* and *less*. The child shared this with a nearby teacher who affirmed her efforts saying, "I see that you counted those leaves. I wonder which pile has more?" The child gleefully responded by showing her the larger stack of leaves.

In a final example, children were in the play yard while it was raining, which sparked an organic discussion about where rain comes from (Practice 1: Asking scientific questions). One child offered that it was raining "because there is lightning." Another child disagreed, offering that it was raining "because the clouds are full" (Practice 7: Engaging in argument

TABLE 2

Scientific and engineering practices: Examples and environmental stage-setting.

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TABLE 2 (CONTINUED)

Scientific and engineering practices: Examples and environmental stage-setting.

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7. Engaging in argument from evidence	Students are digging in the dirt when one holds up something shiny and declares, "I found a crystal!" A second student counters, "No it's not. It's just mica." The first student responds, "Well, mica is a kind of crystal." The second student examines the rock, peeling off layers before concluding, "Yep. This is mica."	A variety of materials are accessible to children throughout the day. They are given flexibility and agency over where and how they use these materials so that they can collect data, construct explanations from evidence, and engage in argument with their peers.
8. Obtaining, evaluating and communicating information	Students describe their garden and explain that it's time to put the plants "to bed" because they're done growing but they will grow again next year.	Gardens offer experiences in stability and change as well as opportunities where children can examine plant parts. In the preschool program, children notice shifting seasons and make observations related to those changes.

TABLE 3

A framework for supporting scientific and engineering practices in play.

OBSERVE	REFLECT	SET THE STAGE	CONNECT
Student asks, "Why are all the leaves turning yellow?" (P1 / P4)	How can I create more opportunities for these types of questions and observations?	Provide baskets or tins for collecting leaves; set out paper and crayons so students can draw what they observe; Articulate the science (e.g., "You made an observation about the leaves" or "I wonder what other things are changing as the weather gets cooler?"	Let children share their drawings and observations; Make leaf rubbings together; Read a story about trees or changing seasons (e.g., *It's Fall!* By Linda Glaser; *Leaf Man* by Lois Ehlert)
Children excitedly announce, "It's raining!" or "It's snowing!"	How can I help children to investigate water in all of its forms?	Provide scoops, shovels, and buckets for water play. Make sure children have rain gear/ snow gear so they will be comfortable outside in wet conditions	Help students to water plants or an outside garden; Ask them what they notice about rain or snow. Read a story about water (e.g., *All the Water in the World* by George Ella Lyon and Katherine Tillotson or *Come on, Rain!* by Karen Hesse with pictures by Jon J. Muth)

from evidence). While these children hold naïve conceptions about the science concept (precipitation), they are engaging in practices central to the development of scientific reasoning. These conversations allow an observant teacher to build on what children already know and then scaffold further questions and conversation about rain.

GETTING STARTED

So how can you begin setting the stage for children's engagement with science and engineering during free play? We suggest using this framework: Observe, Reflect, Set the Stage, Connect (Table 3). Using the *NGSS* scientific and engineering practices as a reference, listen and *observe* as children play. *Reflect* by thinking about how you can support investigation of the questions children ask or how you can extend their exploratory play by *setting the stage* with loose parts or other materials in the play space. Finally, *connect* the science and engineering in children's free play with the books you are reading and the more structured activities you do together in the classroom. In this way, you can harness the natural curiosity and scientific thinking children bring to their play and help them articulate what you see. They are scientists!

CONCLUSION

There is a clear and organic link between children's play and scientific investigation (Gopnik 2012). The release of the *NGSS* and the inclusion of scientific and engineering practices as one of the three dimensions of science learning articulated in those standards provide early childhood educators with the language to identify those practices, even in budding form, in children's play. When given the time and space to explore their environment, children naturally ask questions, make observations, design investigations, collect data, and communicate their observations, and reasoning. We have seen that these opportunities are amplified when children are given time and space to play and explore freely and when teachers are empowered to set the stage for children's exploration and to help children articulate the science in their play.

While more research needs to be done, recent studies suggest that children may be best-served in the development of scientific reasoning and process skills when teachers refrain from disrupting play or engaging in direct instruction (Akman and Özgül 2015; Bonawitz et al. 2011). We found that, in programs built around nature and play-based curricula, children were able to engage with multiple scientific and engineering practices on a daily basis and their teachers were able to connect those instances with some of the crosscutting concepts and disciplinary core ideas of the NGSS. Further, teachers in these programs were able to use the eight scientific and engineering practices as a way of articulating what they observed and as an anchor for dialogue with other teachers about the science unfolding in children's free play. We are optimistic that this model could be used to inform professional development and to generate further conversation about the importance of fostering practices of science and engineering in early elementary learning environments. Finally, we hope that by articulating the science and engineering in children's play, teachers will find rich intersections between "free play" and the more structured activities and investigations they approach together in the classroom.

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