A Hearts-on, Hands-on, Minds-on Model for Preschool Science Learning

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Children are full of wonder concerning the natural world. They instinctively ask how, what, and why questions about their surroundings. Fostering this interest supports the development of children's ideas about the world and their budding understanding of the natural sciences. Nurturing their curiosity can lead to increased learning and the development of verbal and linguistic skills.

Effective science instruction in preschool classrooms offers children opportunities to negotiate and explore new materials. Engaging young children with science concepts is important for cognitive, social, and emotional development. Working in professional development workshops with preschool teachers and child care workers, we authors (an early childhood science education researcher and a classroom teacher/doctoral student) combined our knowledge of young children's developmental needs and the effectiveness of the 5E Learning Cycle to propose a model for science instruction in preschool classrooms—a model that centers on play. With funding support from a state department of education, we designed a model that was developmentally appropriate for preschool, implemented it in preschool classrooms, and modified the model based on observations and conversations with both preschool children and their teachers.

Play in preschool classrooms

Play is the work of preschool children, and exploration is integral to children's science learning. Giving

preschoolers time to explore and play with new materials is an important part of the learning cycle. Before beginning a classroom investigation, teachers encourage children to explore the new materials in their own ways and use their own language to discuss their experiences. This time of play and exploration fosters implicit learning, which is incidental and organic in the play experiences and provides the foundation for explicit intentional learning in the lessons that follow.

The 5E Learning Cycle and Preschoolers

The 5E Learning Cycle (Bybee et al. 1989), touted as an effective instructional model for decades, has been widely used in elementary classrooms. This model includes five steps, or phases: (1) engagement, (2) exploration, (3) explanation, (4) elaboration, and (5) evaluation. Research not only points to the model's instructional effectiveness, but to its constructivist roots, which use and build on the learner's prior experiences and knowledge in the individual's construction of meaning (Glasson & Lalik 1993). Below, each step or phase of the original 5E model is discussed to help us better explain the basis of this modified learning cycle that is developmentally appropriate for even the youngest learners.

During the first phase, *engagement*, the teacher fosters children's curiosity about the targeted concept and links it to their prior knowledge. In the *exploration* stage, children interact with materials in hands-on learning experiences. During these experiences, children use all their senses in observing objects in their environment and comparing similarities and differences between materials and objects. These observations provide valuable data for the children and their teachers.

Explanation provides an opportunity for children to discuss and identify patterns in the data they collected during exploration. Teachers also label the learning during explanation by providing scientific terms and applying them to the concepts observed during exploration. *Elaboration* allows children an opportunity to apply their learning in a new context, facilitating a deeper understanding of the concepts. Elaboration experiences may involve designing a new investigation or simply finding materials at home that have similar properties to the ones explored in class.

When properly implemented, *evaluation* occurs throughout the lesson. For example, the teacher evaluates the students' prior knowledge and identifies possible misconceptions that may be constructed or reinforced during engagement. The application or development of science process skills may be assessed during exploration and explanation. Process skills are of increasing importance for all students, particularly in terms of participation and access among underrepresented populations in science and under the Next Generation Science Standards for grades K–12. Science process skills develop over long and repeated engagements that build on predictions and observations from day to day, year to year. In addition, the National Science Teacher's Association describes the foundations of these skills as beginning with activities that "allow children to question, explore, investigate, make meaning, and construct explanations and organize knowledge by manipulating materials" from environments created with intention (NSTA 2014).

The preschool learning cycle builds on this 5E model and incorporates play.

The preschool learning cycle model we describe here builds on this 5E instructional model and current science educational recommendations; it also incorporates the critical component of play.

In a preschool classroom, special interest tables or stations provide a great way to introduce the play phase, which is essential for implicit learning. Implicit learning occurs when young children engage based on their own curiosities and questioning processes. This incidental learning time is crucial to young children as they begin to build their own meaning(s) from their experiences with materials, tools, and peers. Sensory tables, water tables, and science stations provide designated areas for material use. Because sand and soil can be messy in an open classroom, providing dedicated stations serves as an excellent context for constructive exploration. For other applications, the dramatic play area offers a natural setting for staged events, such as a pretend camping area to talk about the day and night skies. Children can explore motion with cars and ramps in the block area. With careful planning, the design of preschool classrooms provides places and spaces for incorporating and supporting play in science learning.

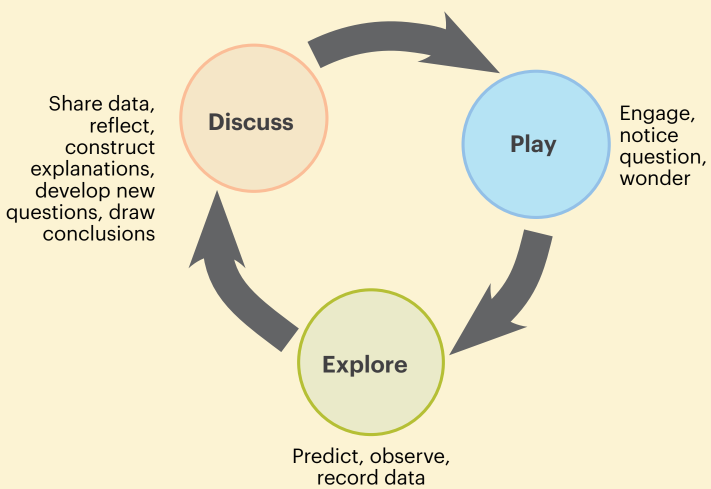
Lev Vygotsky, an early 20th-century pioneer in developmental psychology, advocated the use and manipulation of objects in children's play as a significant component in their thought development (1967; 1978). Children's play can be both experiential and emergent. That is, children bring background knowledge to their play activities and share their experiences with peers through playful interactions. Social negotiation during play—a time of implicit learning—creates new and shared meanings for children.

Play also inspires growth and intellectual development in language, literacy, logic, and mathematics (Van Hoorn et al. 2011). Empirical evidence supports the importance of play within the preschool curriculum. For example, one recent study explored children's use and manipulation of toys (Cook, Goodman, & Schulz 2011). The results provide evidence that children can discern between activities that add to their understanding and those that are either unfruitful or do not add to their own understandings. For example, if a child is given a toy with two buttons, where one button does nothing and the other produces a light and a sound, the children quickly learn which actions are helpful in the operation of the toy and which are not. Therefore, even during play, children will use objects in ways that will help them study the mechanisms, properties, and nature of the materials.

The preschool learning cycle: Hearts on, hands on, and minds on

Our learning cycle is a condensed, three-part version of the 5E model. Our ongoing process begins with play, moves to exploration, and incorporates discussion. (See "Preschool Learning Cycle.") After discussion, the children move back to play to apply their learning with the now familiar materials. This model takes a holistic approach by incorporating *hearts-on*, *hands-on*, and *minds-on* learning, thus addressing children's emotional, social, and cognitive needs. Addressing the whole child while engaging children with science

Preschool Learning Cycle



allows teachers to build more meaningful and effective classroom learning experiences.

Play: Hearts-on learning

During the play phase, children and teachers focus on the hearts-on aspect of learning to stimulate children's curiosity and creativity. Children engage with familiar as well as new materials. Play allows children to share learning experiences with one another. In this phase, we provide opportunities for children to independently explore the materials around them. As they explore, children ask questions and wonder about the materials they experience and the phenomena they naturally observe.

> Children's imaginative play is our starting point for instruction as we ask questions to draw out children's ideas.

We familiarize young children with concepts and materials before a planned exploration. For example, to foster play in an investigation of the properties of matter, we place various materials representative of different states of matter in stations days before beginning an exploration. In the water table, we include plastic blocks, wooden blocks, and hydrophilic "instant" snow and hydrophobic "magic" sand—materials that interact with water in different ways. We give children time and opportunities to use these materials in their own ways while we observe their play. To focus the children's attention, we ask questions about the materials' properties: "How does the water feel?," "How does the plastic block feel?," "How does the plastic block feel in water?," "How does the plastic block look in water?" Then we extend these types of questions in the next stage, exploration.

Exploration: Hands-on learning

From play, our model moves to the exploration phase, which fosters more explicit and intentional learning. In this phase, teachers continue asking questions to expand ideas the children expressed during implicit learning through play. By asking questions that guide children to plan, predict, observe, and record data,

we build on their incidental learning with intentional instruction to foster explicit learning.

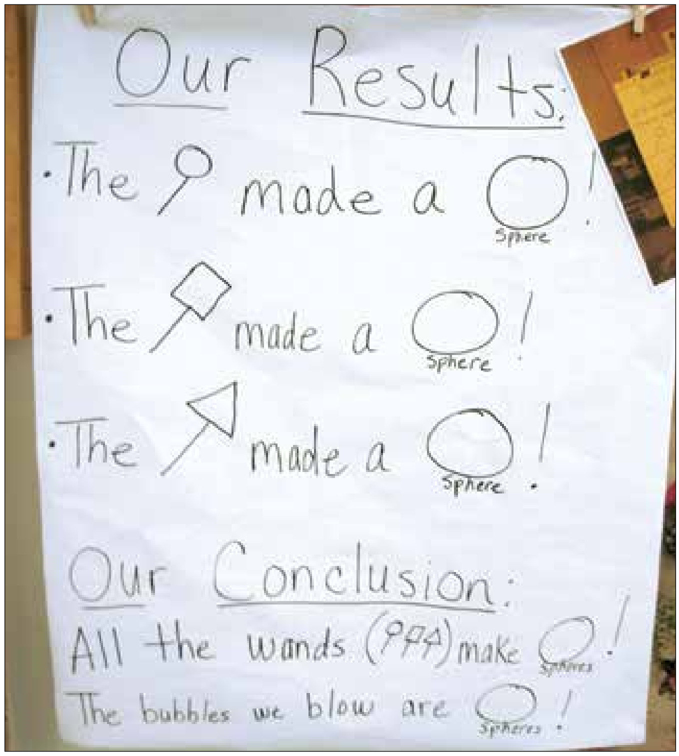
Children's imaginative play is our starting point for instruction as we continue to ask questions to draw out children's ideas while they observe properties of matter. For example, while playing with blocks and goo, or oobleck, children may try to use the goo as a building material or cement. We ask questions about children's play as they explore the goo's properties: "How are you using the goo?," "Is it working for you?," "What are some other ways you can think of to use the goo?" Children's responses can be creative or silly as they note properties of the goo: "The goo gets melty in my hand but not on the table," "It sticks to itself, but not to the blocks."

The children make excited observations about the drying process over several days, leading to comments like these: "It dried! But it didn't keep the blocks together," "It's not gooey anymore. It's crusty, like dried-up toothpaste." The children's building experiences with goo are one example of ways preschoolers can engage in scientific processes while playing.

When the children explore materials, we emphasize that observation is not limited to sight. Observations can involve all senses: touch, smell, sound, sight, and sometimes taste, when safe and appropriate. We use questions to focus the children's attention on the objects or phenomena they experience. For example, we ask, "What color is the sky right now?" during a lesson on evidence for day and night. We continue this line of questioning by linking the concepts to children's personal experiences: "What are some things you can see in the sky during the day?," "What are some things you can see in the sky during the night?," "What kinds of sounds do you hear at recess, during the daytime?," "What sounds do you hear outside right before bedtime at night?," "How does the air feel against your face during the daytime?," "How does the air feel different against your face at night?"

Data representation is an important component of the exploration phase. In addition to developing critical science process skills and introducing the nature of science (i.e., in science what we know is based on what we see, hear, and observe with our senses), data representation provides opportunities to incorporate other preschool content standards (e.g., literacy, mathematics). For preschoolers and scientists alike, data recording often means drawing. Drawing focuses children's observational skills, gives them opportunities to communicate their observations, and helps them develop their fine motor skills. Children's drawings provide teachers with a window into their minds. Observational drawings are important components in both the project approach (Helm & Katz 2010) and Reggio Emilia schools (Edwards, Gandini, & Forman 1998). Both are known for their use of drawing with children as young as 2 years. Research finds that children often represent their ideas through drawing with greater ease and relaxation than adults do (Helm & Katz 2010).

Children, with teachers' support, typically record data with text through shared writing or as a large group. However, as students gain independence and develop fine motor skills, we help them move toward the creation of their own data tables. For example, when children observe and record properties of plants, we write their notes on a poster board. Children record their data by cutting colored paper into squares and



taping the squares to the poster to represent the numbers of plants with flowers. They practice using relative terms, such as *less than* and *greater than,* when comparing quantities.

We use student and class data representations in different ways. For example, the chart labeled "Our Results" was constructed by a group during circle time after an investigation of bubble wands and bubble shapes. We used questions to draw the children's attention to the shape of the bubble wands and then back to the evidence. Depending on the age of the preschoolers, we can construct such a chart during the investigation. For example, if the children are very young or have limited attention, they explore the bubble wands one at a time and then come back together at circle time to fill in the observed data. Scientific words (*spheres* in this example) are introduced and applied to the data chart at the end of the exploration. We then focus the children's attention on the words and their observations.

Discussion: Minds-on learning

After data collection and representation, children and teachers step back to look at what the data tell them. During the discussion phase, teachers help children construct reasonable explanations from their data. We summarize the findings with the children and label the learning. During this labeling, we scaffold language by linking the words children use to describe phenomena with the language of science. This discussion begins to move children's ideas toward more scientific understandings of the concepts.

When we ask questions and guide children to make meaning of and construct reasonable explanations based on their data, preschoolers often come up with creative explanations for everyday phenomena: "The magnet must have legs to jump!," "These stick together because they are friends," "The two red ends [of a red and blue bar magnet] don't like each other because it's too much red; it looks better with blue so they stick together." Preschoolers have emerging reasoning skills and judgment-making abilities. We help children develop their process and reasoning skills by drawing attention back to their evidence. We ask them if the evidence they collected supports their claims. Our intent is not to correct preschool children's answers, but to foster a scientific mindset. We make connections back to the observed data to construct reasonable explanations from the evidence, which reinforces that science is evidence based.

After the discussion and follow-up, children return to play and engage with the materials in new ways, based on their new knowledge and scientific vocabulary. Guided by children's interests in topics, we design lessons to allow learning to unfold over a week or longer as the children continuously engage with and discuss the materials in new ways.

A learning cycle example using magnets

Everyone, including young children, has experiences with magnets. Many toys include magnets (e.g., Magna-Tiles, MagnaDoodle, Thomas the Tank Engine), and both adults and children use magnets to display artwork or lists on refrigerators.

Play

To start this learning cycle, we ask children for examples of ways they have used magnets. By linking the magnets to the children's prior experiences, we engage them in the hearts-on aspect of our learning cycle. Typical responses include "My mommy made a magnet with my picture on it" and "I picked out a magnet to bring home from vacation."

We also use this time to discuss appropriate behaviors and safety issues regarding the materials. We use materials and magnets that children can safely explore based on size and composition. For example, we have only large magnets in our preschool classroom, and we demonstrate safe ways to explore with them. We remind children of our classroom community expectations: keep all materials away from our own faces and those of our friends, keep materials on the table or floor, and keep magnets away from electronic objects, like computers and computer screens. After we address safety considerations, the children investigate magnets in their own ways at the sensory table. The children are provided with a large variety of objects to explore: liquids (water or colored water) and various solids. Teachers can intentionally supply solids that are metallic (paper clips, coins, jewelry), nonmetallic (tongue depressors, large marbles), and other items such as paper, rocks, gemstones, seeds, soil, or plants for children to explore with magnets.

Explore

Next, in small or large groups, we introduce a hands-on magnet investigation to the children by asking, "What happens when you put two magnets together?" We organize the children around tables and focus their attention on the exploration. We challenge the children, using two magnets, to touch only one magnet and use it to make the other magnet move. As they engage in this investigation, the children come up with words to describe different ways the magnet moves (e.g., *slide, swing, hop*). "One magnet *hops* to the other!"

Discuss

Moving from hands-on exploration to minds-on discussion, the children use their own language to describe their observations. Their observations typically relate to their lives: "These magnets don't like each other!," "He is the superhero chasing the bad guy," "These two are in love! They are kissing." As children share the list of words (verbs) they used to describe the interactions between the magnets, the children, with teacher support, create a class list of their observations. This process allows children to record and share data. After discussion, we scaffold their observations and their words to help them see that all interactions between the two magnets were either one magnet pushing away from the other magnet or pulling toward it. Based on the children's developmental levels and their prior knowledge, they may be ready to go beyond this simple description and learn the scientific terms *attract* (a pull toward) and *repel* (a push away).

Return to play

After the investigation and discussion, the magnets and materials remain in the activity center for further exploration. Later, to encourage new experiences, we move the magnets to a new center and add different materials to the familiar ones, while continuing to use words like *attract* and *repel* so that children have multiple opportunities to expand their vocabularies. Depending on the children's discourse, the teachers may opt to provide different intentional materials and experiences to build on the data the children are already collecting and discussing informally. For example, if children begin to hypothesize that all shiny objects will be attracted to magnets, teachers might provide materials with a shiny luster that are not magnetic (e.g., aluminum foil) to challenge the children's thinking and increase their meaning-making process.

The preschool learning cycle for science can also be modified to allow the instructional sequence to unfold at a slower pace to accommodate more scaffolding and/or student curiosity, and to allow for further and longer-term engagement. For example, children may spend one session exploring how they can "make the magnets behave as friends," and the class discusses attraction. The following day, the children may explore how they can make the magnets play a game of chase in which one runs from the other, and the class discusses repulsion. In both types of instructional sequences, play and discussion are incorporated within each lesson regardless of how many days are devoted to learning about magnets. Regardless of the time sequencing, the *hearts-on*, *hands-on,* and *minds-on* aspects of instruction accompany each investigation with the materials.

Conclusion

This preschool learning cycle is aligned with young children's developmental needs. It integrates effective science learning experiences with developmentally appropriate instruction for young children. Our model can be applied to many science concepts (e.g., observable properties of day and night, ramps and motion, and of objects like rocks). The intent of our instruction is not to obtain correct or incorrect answers to closed questions. Rather, we ask productive, open-ended questions that children can answer through their own observations in the context of well-designed explorations, questioning, and development of science process skills. Children make observations and draw conclusions from these observations. To assist children in constructing meaning from their experiences, we ask questions initially to focus their attention and later to help them find patterns in their observations. This stage allows teachers to home in on particular science process skills, as well as focus on the explicit learning of academic language. We use this model to build on children's interests, foster their natural curiosity, develop their inquiry skills, and promote effective science learning.

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