

Promoting the Development of Scientific Thinking

By Ruth Wilson, Ph.D.

Some people think of science as learning facts about the world around us. Others think of science and other ways of knowing as “the having of wonderful ideas” (Duckworth, 1987). This latter view of science and ways of knowing match the characteristics of young children as learners. Young children are naturally curious and passionate about learning (Raffini, 1993). In their pursuit of knowledge, they’re prone to poking, pulling, tasting, pounding, shaking, and experimenting. “From birth, children want to learn and they naturally seek out problems to solve” (Lind, 1999, p. 79).

Such attitudes and actions on the part of young children indicate that they engage in scientific thinking and actions long before they enter a classroom (Zeece, 1999). Unfortunately, when science education is introduced in a formal setting, it often reflects the understanding of science as the learning of facts. This approach has led some educators to suggest that “most science learning that takes place in formal settings is not true science” (Zeece, 1999, p. 161). This article will discuss the benefits of active, hands-on learning, goals for early childhood science programs, and suggestions for fostering scientific learning in the early childhood classroom.

Science as Active Exploration

While it is appropriate to introduce older students to science history and expect them to learn facts discovered by others, young children should learn science (and all other areas of study) through active involvement – that is, through first-hand, investigative experiences. Young children should be involved in “sciencing” versus the learning of scientific facts presented by others (Kilmer & Hofman, 1995; Mayesky, 1998; Zeece, 1999). Sciencing is a verb and suggests active involvement. Such involvement should be both hands-on and minds-on in nature. Thus, children should be engaged both physically and mentally in investigating and manipulating elements in their environment (Chaille & Britain, 2003; Kilmer & Hofman, 1995). To be developmentally appropriate and to be in compliance with national guidelines for the teaching of science, science education at the preschool and primary level must be “an active enterprise” (Lind, 1999, p. 73). Both the National Science Education Standards (National Research Council, 1996) and Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) call for an action-oriented and inquiry-based approach to science with young children. As articulated by Lind (1999), “the best way

to learn science is to do science” (p. 74).

Therefore, science for young children should involve asking questions, probing for answers, conducting investigations, and collecting data. Science, rather than being viewed as the memorization of facts, becomes a way of thinking and trying to understand the world. This approach allows children to become engaged in the investigative nature of science (Kilmer & Hofman, 1995; Lind, 1999) and to experience the joy of having wonderful ideas (Duckworth, 1987).

Discovery Learning

Teachers can't give children “wonderful ideas”; children need to discover or construct their own ideas. Developing new concepts or ideas is an active process and usually begins with child-centered inquiry, which focuses on the asking of questions relevant to the child. While inquiry involves a number of science-related activities and skills, “the focus is on the active search for knowledge or understanding to satisfy students’ curiosity” (Lind, 1999, p. 79). Knowing the right answer, then, is not one of the primary objectives of science in the early childhood curriculum. Duckworth (1987) refers to “knowing the right answer” as a passive virtue and discusses some of its limitations. “Knowing the right answer,” she says, “requires no decisions, carries no risks, and makes no demands. It is automatic. It is thoughtless” (p. 64). A far more important objective is to help children realize that answers about the world can be discovered through their own investigations. Sciencing, for example, involves coming up with ideas of one's own. Developing these ideas and submitting them to someone else's scrutiny is, according to Duckworth (1987), “a virtue in itself—unrelated to the rightness of the idea” (p. 68).

Developing ideas of one's own add breadth and depth to learning. This is so, even if the child's initial ideas are inaccurate views of the world. Duckworth (1987) explains: “Any wrong idea that is corrected provides far more depth than if one never had a wrong idea to begin with. You master the idea much more thoroughly if you have considered alternatives, tried to work it out in areas where it didn't work, and figured out why it was that it didn't work, all of which takes time” (pp. 71-72).

Science Goals

Desired goals of science in the early childhood curriculum include what we hope children will attain or achieve in three different areas: content, processes, and attitudes or dispositions. Content refers to the body of knowledge representing what we know about the world. Children's body of knowledge develops and increases over time, and their desire to communicate and represent their knowledge should be acknowledged and supported.

The processes, or process skills, represent the active component of science and include such

activities as predicting, observing, classifying, hypothesizing, experimenting, and communicating. Adults should support children in practicing and applying these skills in a variety of activities throughout the day. This can be done by showing a sincere interest in children’s observations and predictions and by providing a variety of materials and settings that invite experimentation.

Certain attitudes or dispositions are also central to scientific inquiry and discovery. These include curiosity, a drive to experiment, and a desire to challenge theories and to share new ideas (Conezio & French, 2002). Teachers should value these attitudes or dispositions, be aware of how they are manifested in young children, and find ways to acknowledge and nurture their presence.

Productive Questions to Foster Scientific Thinking*

Type of Question	Purpose/Examples	Examples
Attention-focusing	Calls attention to significant details	What is it doing? How does it feel?
Measuring & counting	Generates more precise information	How many? How much? How heavy?
Comparison	Fosters analysis and classification	How are they alike? How different?
Action	Encourages exploration of properties and events; also encourages predictions	What if...?
Problem-posing	Supports planning & trying solutions to problems	How could we...?
Reasoning	Encourages reflection on experiences & construction of new ideas	Why do you think? Can you explain that?

*Adapted from Martens, 1999, p. 26

Science in the Early Childhood Classroom

Science is often sadly neglected in the early childhood classroom (Johnson, 1999). Perhaps this is because science is “perceived and presented as too formal, too abstract, and too theoretical – in short, too hard for very young children and their teachers” (Johnson, 1999, p. 19). Perhaps this neglect is also due to the mistaken idea that the “constructivist” approach to education is incompatible with science education (Johnson, 1999).

A constructivist approach to education is based on the understanding that knowledge is constructed by children versus being given or transmitted to them.

In this approach, children are viewed as “intellectual explorers” (Lind, 1999) and “theory builders” (Chaille & Britain, 2003). This approach assumes that as they interact with the world around them, young children develop their own complex and varying theories about this world.

Teachers working from a constructivist approach provide a supportive environment where young children are encouraged to go about testing and revising their original theories. Key ingredients for a supportive environment include: a) a variety of interesting materials for children to explore and manipulate, b) unstructured time for children to develop and test their own ideas, and c) a social climate that tells the children that questions and experimentation are as valuable as knowing the right answers. Productive questions posed by the teacher at just the right time are also critically important to helping children construct their own understandings. Productive questions are, in fact, one of the most effective tools for supporting constructivist learning (Martens, 1999).

Most children have difficulty constructing understanding simply by engaging in an activity – that is, they “fail to make connections necessary to arrive at a desired understanding” (Martens, 1999, p. 25). Productive questions provide a bridge between what the children already know and what they experience through an activity. Productive questions thus “take a student forward in his or her thinking; they enable a teacher to provide scaffolding for students beginning to build their own understandings” (Martens, 1999, p. 25).

As outlined by Martens (1999) and presented on page 32, there are six different types of productive questions that work well with the constructivist approach to teaching and learning. These questions also support the science curriculum goals in an early childhood classroom. Used strategically, these questions allow teachers to meet students where they are in their thinking and provide the type of scaffolding needed at any given moment (Martens, 1999). The teacher’s choice as to what type of question to use is based on what the teacher hears and sees as the children engage in an activity.

The constructivist approach places the child at the center of the educational process. The teacher’s role in this approach is to serve as observer and facilitator rather than instructor (Chaille & Britain, 2003; Martens, 1999). Science education, however, has long been teacher-centered, with the teacher as the authority figure and the one with all the right answers. Without doubt, such a traditional science program – involving authority-based, teacher-directed instruction – is inappropriate for young children (Johnson, 1999). While best practices in science education at all levels call for a more hands-on, inquiry-based approach, the image of teacher-as-authority persists (Johnson, 1999). This image needs to change, so that young children can reap the benefits of a stimulating science curriculum that nurtures their curiosity and their on-going intellectual

development. Through such a curriculum, children will experience the joy of having wonderful ideas – that is, the joy of finding out.

Science and Young Children: Comparing Approaches

Traditional Approach

- Science viewed as already-discovered knowledge
- Teacher viewed as authority
- Areas of study set by teacher
- Large group instruction and investigations
- Evaluation based on right answers
- Content not connected to children's experiences
- Predetermined parameters around areas of study
- Prescribed ways to collect and record data
- Science viewed as separate area of the curriculum

New Approach

- Science viewed as active exploration
- Teacher viewed as facilitator
- Areas of study set by child interest
- Individual and small group investigations
- Evaluation based on multiple criteria
- Content connected to children's experiences
- Content of study open-ended
- Multiple ways to collect and record data
- Science integrated with other curricular areas

Fostering Scientific Thinking

One of the primary goals of the early childhood science curriculum is the development of scientific thinking in young children. Scientific thinking differs from the learning of scientific facts in that scientific thinking involves children in the process of finding out. Instead of learning what other people have discovered, scientific thinking leads children to make their own discoveries. Scientific thinking is manifest as young children ask questions, conduct investigations, collect data, and search for answers. Scientific thinking is evident, for example, when Jake puts one snowball in an empty bucket while he puts another snowball of about the same size in the water table. "I want to see which one lasts the longest," he says.

Chaille and Britain (2003), in *The Young Children as Scientist*, present a constructivist curriculum model for science and emphasize the importance of scientific thinking. They clearly debunk the notion that the constructivist approach is incompatible with science education. They describe young children as “actively inquiring natural scientists” (p. 20) and learning as “the process of theory building” (p. 5). This view of young children and how they learn is supported elsewhere in the literature where young children are described as being naturally curious and “biologically prepared to learn about the world around them” (Conezio & French, 2002, p. 12). In the above example, Jake knew that snow melts when exposed to warm temperatures. He wasn’t sure, however, if water at room temperature would make any difference in how quickly snow melted. His self-selected experiment was designed to help him find out.

To foster scientific thinking, teachers should view young children as active learners (versus recipients of knowledge) and give them varied opportunities to explore and experiment. Such opportunities will allow children to construct meaning and develop understandings that are not only valid but also valuable to their on-going intellectual development. The teacher, in response to Jake’s experiment, could extend – or scaffold – his learning by posing several productive questions (as presented on page 32) at opportune times. A measuring question would be a good place to start. How many minutes will it take before the snowball in the bucket melts? How many minutes for the snowball in the water table? Action questions and reasoning questions could follow: What would happen if we broke the snowball into smaller pieces? Why do you think the snowball in the water table melted first? Can you invent a rule about how things melt?

An environment that fosters scientific thinking is one that gives young children the time, space, and materials to exercise their curiosity. It also gives them the freedom to engage in child-centered explorations, experimentations, and explanations. Note that in the questions posed in relation to Jake’s experiment, the teacher avoided giving facts or stating rules. The questions posed invited more reflective thinking and further experimentation on Jake’s part. The experiment and the related findings were his, not the teacher’s or someone else’s.

To become engaged in scientific thinking, children need access to materials that they can take apart and the tools to assist them in doing so. They need places where they can dig in the dirt and dip water from a pond. They also need magnifying glasses, measuring tools, buckets, and frequent access to the natural world.

Teachers should take advantage of the different ways science can be naturally integrated into a play-centered curriculum. Science should not be viewed as an “add on” or a separate part of the early childhood program. Sciencing occurs, in many cases, in what children already do and how they think about what they do. As a child experiments with a mixture of oil and water, for example,

she is making observations and predictions. The child is also building theories and testing those theories. These physical and mental manipulations represent the essence of what science is all about.

Children's construction of knowledge can be enhanced through social interactions—that is, by sharing their observations and ideas with each other. Children should be encouraged to work together “in building theories, testing those theories, and then evaluating what worked, what didn't, and why” (Conezio & French, 2002, p. 13). Shared inquiry where children work together can be especially beneficial in fostering curiosity and stimulating new ideas (Chaille & Britain, 2003). One way to involve children in shared inquiry is through solving problems that focus on a specific situation: How can we move this heavy box? or How do we find out what our turtle likes to eat? Shared inquiry generates a number of diverse ideas about the problem and challenges children to communicate the reasoning behind their ideas. There's no doubt that “problem solving and reflective thinking play an important role in children's science learning” (Lind, 1999, p. 80).

Science should be integrated into all the other curricular areas. Math, literacy, social studies, and art can all be linked to science. For literacy, it's easy to introduce and/or reinforce scientific thinking through poetry, storytelling, and non-fiction children's literature. The benefits of such integration, as outlined by Zeece (1999), include:

- providing accurate information in understandable and interesting language;
- offering topical information from varied viewpoints;
- helping children develop inquiring minds and a scientific approach to solving problems in increasingly sophisticated ways;
- presenting models of scientific methods of observation, hypothesis formulation, data gathering, experimentation, and evaluation; and
- fostering an appreciation, understanding, and respect for living things.

Science-based literature should be chosen carefully with attention to both literacy and science concerns in mind. As expressed by Zeece (1999), “Criteria for selection of natural science-based children's literature ideally parallel those used for other high-quality literary resources” (p. 161). Additional considerations, however, relate to how elements of the natural world are represented and presented. With these considerations in mind, Zeece (1999) recommends choosing books with the following criteria in mind:

- current, factual content;
- clear and simple explanations;
- depth and complexity of subject matter closely matched to the developmental and interest level of children in the group;

- beautifully presented illustrations and narrative;
- content consistent with overarching philosophy of the program; and
- completeness and ease of use allowing children to answer questions and/or explore ideas effectively.

Science Concepts Typically Taught During the Preschool Years*

Systems (groups or collections having some influence on one another)

e.g.: parts of the human body; ecosystems (where animals and plants live interdependently)

Models (representations of real objects or phenomenon)

e.g.: word descriptions or drawings; physical models

Constancy and Change (how things change over time)

e.g.: seed to plant; different seasons; growth and decay

Scale (focusing on characteristics and comparisons)

e.g.: size; distance; quantity; weight

Patterns and Relationships (structure and organization of matter)

e.g.: properties of materials; alike and different comparisons; patterns in nature

Cause and Effect (explanations for phenomena)

e.g.: shadows; freezing/melting; gravity

Structure and Function (relationship between characteristic and action)

e.g.: makeup of plants and animals; tools; eating utensils

Variations (discontinuous and continuous properties)

e.g.: sounds; colors

Diversity (variety of types)

e.g.: seeds; leaves; living organisms

*Adapted from Kilmer & Hofman (1995)

Teachable Moments

From this discussion, it should be clear that the science curriculum in an early childhood program should include both teacher planned activities and “spontaneous sciencing.” Teachers should certainly plan a variety of interesting and challenging situations which invite young children to observe, explore, and experiment (Chaille & Britain, 2003). Examples of such situations include teacher-led explorations of the properties of water, characteristics of animals and their habitats, life cycles of plants, and patterns found in nature (seasons, light and shadows, day and night). Many rich opportunities for sciencing, however, occur on a daily basis during unplanned events in the

classroom and on the playground. These opportunities invite spontaneous sciencing and can lead to the “having of wonderful ideas.”

“Spontaneous sciencing occurs whenever a child (or a teacher) sees something of interest and wonders about it” (Kilmer & Hofman, 1995, p. 55). A constructivist teacher recognizes such moments and pauses to observe, reflect, and explore with the children. The occasion may be icicles hanging from the roof, a bird building a nest, or ants at the base of a tree. By stopping to observe and reflect, teachers give children the opportunity to grow in appreciation and understanding of the world around them.

Conclusion

Children are naturally curious about the world and want to find out as much as they can. They want to know what makes the wind blow, how trees grow, why fish have fins, and where turtles go in the winter. But they don't want adults to give them the answers. They want to be the discoverers, the experimenters, and the theory builders. They don't want science to be something that is imparted to them; they want it to be something that they do. They want to be scientists; not just consumers of science. They want to ask their own questions, collect their own data, and arrive at new and wonderful ideas. These “wants” should shape the foundation of an early childhood science curriculum.

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