Science in Early Childhood Classrooms: Content and Process

By Karen Worth

Abstract

There is a growing understanding and recognition of the power of children's early thinking and learning as well as a belief that science may be a particularly important domain in early childhood, serving not only to build a basis for future scientific understanding but also to build important skills and attitudes for learning. This paper addresses the question of what the nature of science teaching and learning in the early childhood classroom should be. It proposes four basic ideas: (1) doing science is a natural and critical part of children's early learning; (2) children's curiosity about the natural world is a powerful catalyst for their work and play; (3) with the appropriate guidance, this natural curiosity and need to make sense of the world become the foundation for beginning to use skills of inquiry to explore basic phenomena and materials of the world surrounding children; and (4) this early science exploration can be a rich context in which children can use and develop other important skills, including working with one another, basic large- and small-motor control, language, and early mathematical understanding. The paper describes a structure for learning through inquiry and criteria for the selection of appropriate content for young children. It concludes with a discussion of implications for the classroom, focusing on child-centered curriculum, the role of materials, the use of time and space, the key role of discussion and representation, and the teacher's role.

Introduction

In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choices that arise every day. Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology. And everyone deserves to share in the excitement and *personal fulfillment that can come from understanding and learning about the natural world.* (National Research Council, 1996, p. 1)

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The need to focus on science in the early childhood classroom is based on a number of factors currently affecting the early childhood community. First and foremost is the growing understanding and recognition of the power of children's early thinking and learning. Research and practice suggest that children have a much greater potential to learn than previously thought, and therefore early childhood settings should provide richer and more challenging environments for learning. In these environments, guided by skillful teachers, children's experiences in the early years can have significant impact on their later learning. In addition, science may be a particularly important domain in early childhood, serving not only to build a basis for future scientific understanding but also to build important skills and attitudes for learning. A recent publication from the National Research Council supports this argument:

Children who have a broad base of experience in domain-specific knowledge (for example, in mathematics or an area of science) move more rapidly in acquiring more complex skills…. Because these [mathematics and science] are "privileged domains," that is, domains in which children have a natural proclivity to learn, experiment, and explore, they allow for nurturing and extending the boundaries of the learning in which children are already actively engaged. Developing and extending children's interest is particularly important in the preschool years, when attention and self-regulation are nascent abilities. (Bowman, Donovan, & Burns, 2001, pp. 8-9)

This growing understanding of the value of science in early education comes at a time when the number and diversity of children in child care settings and the number of hours each child spends in such settings is increasing. Growing numbers of children live in poverty. More and more grow up in single-parent homes and homes in which both parents work. Media have become commonplace in the lives of the very young. Thus, experiences that provide direct manipulation of and experience with objects, materials, and phenomena—such as playing in the sink, raising a pet, or going to the playground—are less likely to occur in the home. More and more, it is in the early childhood classroom where this kind of experience with the natural world must take place, allowing all children to build experiences in investigation and problem solving and the foundation for understanding basic science concepts.

What Is Science?

Science is both a body of knowledge that represents current understanding of natural systems and the process whereby that body of knowledge has been established and is continually extended, refined, and revised. Both elements are essential: one cannot make progress in science without an understanding of both. Likewise, in learning science one must come to understand both the body of knowledge and the process by which this knowledge is established, extended, refined, and revised. (Duschl, Schweingruber, & Shouse, 2007, p. 26)

Before turning to a deeper discussion of science for the very young, it is helpful to describe our view of science. The goal of science is to understand the natural world through a process known as scientific inquiry. Scientific knowledge helps us explain the world around us, such as why water evaporates and plants grow in particular locations, what causes disease, and how electricity works. Scientific knowledge can help us predict what might happen: a hurricane may hit the coast; the flu will be severe this winter. Scientific knowledge can also help solve problems such as unclean water or the spread of diseases. Science can guide technological development to serve our needs and interests, such as high-speed travel and talking on the telephone.

Science means different things to different people. Some think of it as a list of facts once memorized in school. Others understand it as a body of knowledge, including facts, concepts, principles, laws, theories, and models that explain the workings of the natural world. But, as is clear from the quote above, science is more than knowledge and information; it also is a process of studying and finding out—which we call scientific inquiry or science practice. According to the National Science Education standards, “Science inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on evidence from their work” (National Science Research Council, 1996, p. 23). Many scientists also speak of the fun and creativity of doing science. A famous scientist, Richard Feynman, once said of his work, “Why did I enjoy doing it (physics)? I used to play with it. I used to do whatever I felt like doing… [depending on] whether it was interesting and amusing for me to play with” (Feynman, 1997, p. 48).

Some people, when they think of people doing science, imagine laboratories filled with scientists in white coats mixing chemicals and looking through microscopes. Such images are real, but there are other images of scientists charting the course of a hurricane, studying the behaviors of wolves, searching the skies for comets. But scientists are not the only people who do science. Many jobs involve science, such as electrician, horticulturalist, architect, and car mechanic. And people of all ages learn about the world through actions that begin to approximate scientific practice—for example, when an amateur gardener asks a question, “How much light does my geranium need to flower well?”, tries out different locations, and observes the results. These activities, by scientists and nonscientists, whether happening in the laboratory, in the field, or at home, have in common the active use of the basic tools of inquiry in the service of understanding how the world works. Children and adults, experts and beginners, all share the need to have these tools at hand as they build their understanding of the world.

The Science of Young Children

May 12: Today I asked the kids at the snail table to draw pictures of the snails. Christine was reluctant at first, saying she didn’t want to draw, she just wanted to play with the snails. I gave her a choice then—saying she could draw pictures of snails or play in a different area. She said, okay then, she’d draw. Her snail pictures involved a lot of zigzaggy lines, and I tried to understand what they represented to her. Then after awhile I figured out that the zigzags were the paths where the snail moved. So at lunch I arranged for the kids who hang out by the snail table to sit together and I joined them. And we talked snails. Christine talked about how the snail feels when it walks on her arm (“kind of sticky and slimy, kinda slippery”). Christine said that some kind of “slime” comes out from the bottom part and makes the snail move; Ena stood up and demonstrated that the snail wiggles his tail/bum, saying that pushed him. Delmy said the snail walks like we walk but just with two feet. Joanna said he goes slow and demonstrated by walking two fingers lightly and slowly across the table; and John said the snail runs fast with lots of feet.

May 16: Ever since Christine drew her zigzag pathway picture and we had our snail talk over lunch, I've been thinking about ways to get kids thinking more about how snails move. So, I had the idea to cover a table with easel paper and have the kids follow the path of some snails with pencil and see the shape of the trails they made. At first, Christine just wanted to play with snails, and I said okay, but then when she saw the other kids tracing the paths of different snails, she wanted to join in, too. After awhile, they used string to track the snail trails and ended up with different length lines and loops.

Excerpts from Cindy Hoisington's Journal (reprinted with permission)

These notes provide an image of science teaching and learning in the early childhood classroom in which teachers and children are engaged in inquiries into scientific phenomena—animal behaviors and, more specifically, the behaviors of snails. They suggest the potential of 3- to 5-year-old children to engage in the practices of science. These notes also provide a small window into science for young children that is based on several beliefs that have guided my work: (1) doing science is a natural and critical part of children's early learning; (2) children's curiosity about the natural world is a powerful catalyst for their work and play; (3) with the appropriate guidance, this natural curiosity and need to make sense of the world become the foundation for beginning to use skills of inquiry to explore basic phenomena and materials of the world surrounding children; and (4) this early science exploration can be a rich context in which children can use and develop other important skills, including working with one another, basic large- and small-motor control, language, and early mathematical understanding.

The Content of Science for Young Children

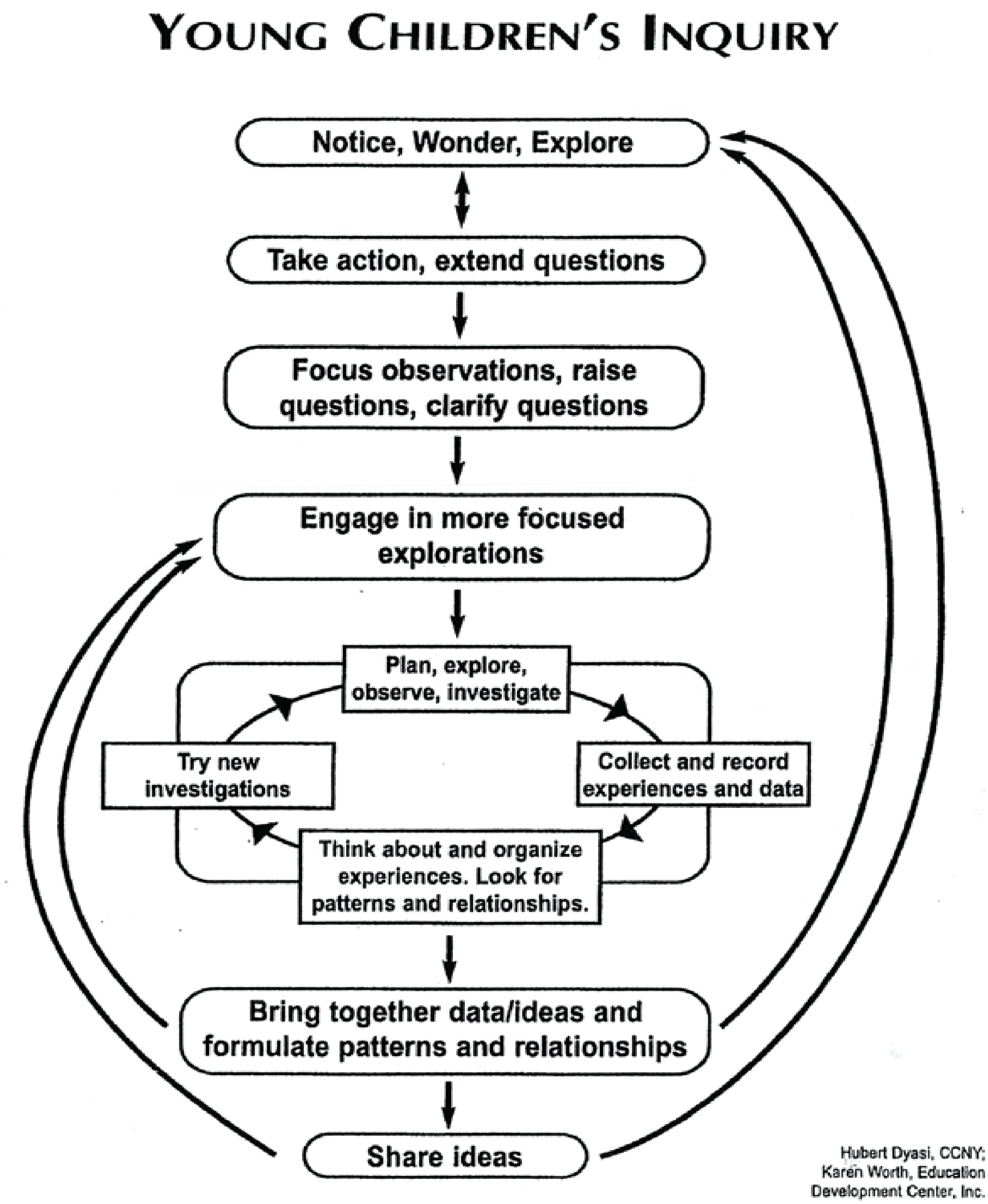
Children entering school already have substantial knowledge of the natural world, much of which is implicit…. Contrary to older views, young children are not concrete and simplistic thinkers…. Research shows that children's thinking is surprisingly sophisticated…. Children can use a wide range of reasoning processes that form the underpinnings of scientific thinking, even *though their experience is variable and they have much more to learn.* (Duschl, Schweingruber, & Shouse, 2007, pp. 2-3)

The content of science for young children is a sophisticated interplay among concepts, scientific reasoning, the nature of science, and doing science. It is not primarily a science of information. While facts are important, children need to begin to build an understanding of basic concepts and how they connect and apply to the world in which they live. And the thinking processes and skills of science are also important. In our work developing curriculum for teachers, we have focused equally on science inquiry and the nature of science, and content—basic concepts and the topics through which they are explored. In the process of teaching and learning, these are inseparable, but here I discuss them separately.

Science Inquiry and the Nature of Science

The phrase "children are naturally scientists" is one we hear often. Their curiosity and need to make the world a more predictable place certainly drives them to explore and draw conclusions and theories from their experiences. But left to themselves, they are not quite natural scientists. Children need guidance and structure to turn their natural curiosity and activity into something more scientific. They need to practice science—to engage in rich scientific inquiry.

In our work, we have used a simple inquiry learning cycle (Worth & Grollman, 2003, p. 19) to provide a guiding structure for teachers as they facilitate children's investigations (Figure 1). The cycle begins with an extended period of engagement where children explore the selected phenomenon and materials, experiencing what they are and can do, wondering about them, raising questions, and sharing ideas. This is followed by a more guided stage as questions are identified that might be investigated further. Some of these may be the children's questions, others may be introduced by the teacher, but their purpose is to begin the process of more focused and deeper explorations involving prediction, planning, collecting, and recording data; organizing experiences; and looking for patterns and relationships that eventually can be shared and from which new questions may emerge. This structure is not rigid, nor is it linear—thus the many arrows. And while it is used here to suggest a scaffold for inquiry-based science teaching and learning, it closely resembles how scientists work and, in interesting ways, how children learn.



Scientific inquiry provides the opportunity for children to develop a range of skills, either explicitly or implicitly. The following is one such list:

- Explore objects, materials, and events.
- Raise questions.
- Make careful observations.
- Engage in simple investigations.
- Describe (including shape, size, number), compare, sort, classify, and order.
- Record observations using words, pictures, charts, and graphs.
- Use a variety of simple tools to extend observations.
- Identify patterns and relationships.
- Develop tentative explanations and ideas.
- Work collaboratively with others.
- Share and discuss ideas and listen to new perspectives.

This description of the practice of doing science is quite different from some of the science work in evidence in many classrooms where there may be a science table on which sit interesting objects and materials, along with observation and measurement tools such as magnifiers and balances. Too often the work stops there, and little is made of the observations children make and the questions they raise. Another form of science is activity-based science where children engage in a variety of activities that generate excitement and interest but that rarely lead to deeper thinking. There are a multitude of science activity books that support this form of science in the classroom. Thematic units and projects are yet other vehicles for science work in the classroom. These can be rich and challenging; however, they may not have a focus on science. Transportation or a study of the neighborhood are typical examples that have the potential for engaging children in interesting science but frequently focus more on concepts of social studies.If these projects or themes are to truly engage students in science, care needs to be taken to be sure that science is in the foreground, and the integration with other subject matter is appropriate and related to the science.

Science Content

With an of the practice of science that guides how we approach science inquiry in the early childhood classroom, we turn to the question of the content of science for this age. There are many phenomena that can be explored, many questions to be explored, many basic concepts to be introduced, and many topics to choose from, so rather than make a list of possible subject matter and topics, following are key criteria for guiding decisions about topic selection.

At the core of inquiry-based science is direct exploration of phenomena and materials. Thus, the first criterion is that phenomena selected for young children must be available for direct exploration and drawn from the environment in which they live. The study of snails is an example of an exploration that meets these criteria. Others include light and shadow, moving objects, structures, and plant and animal life cycles. Examples of some that do not meet these criteria include such popular topics as dinosaurs or space travel. While these are often brought up by children because they are part of the media environment around them, they are not appropriate content for inquiry-based science in the classroom because they present no opportunity for direct exploration on the children's part and even the simplest explanatory ideas are developmentally problematic. Other topics often chosen in early childhood classrooms such as the rain forest or animals of the Arctic (polar bears and penguins) may be based in appropriate concepts (habitat, physical characteristics, and adaptation of animals), but these too lack the possibility for direct engagement. Topics such as these need not be excluded. They can be the subject of important dramatic play, elaborate discussion, and exploration using books and other secondary sources. The problem arises when they take time away from or substitute for inquiry-based science experiences.

The second criterion is that the concepts underlying the children's work be concepts that are important to science. For example, in the exploration of snails, the underlying concept is the behavior of animals and how behaviors are related to physical structure and an animal's way of meeting its needs. Such an experience provides a base from which children will gradually develop an understanding of adaptation and evolution. Studying shadows is another example, where children's experiences build a foundation for understanding a key concept about light—

that it travels in straight lines. Working with balls on ramps is yet another example where skillfully guided experiences build a foundation for later understanding of forces and motion.

A third criterion is that the focus of science be on concepts that are developmentally appropriate and can be explored from multiple perspectives, in depth, and over time. When children have many and varied opportunities to explore a phenomenon, they come to the final stages of inquiry with a rich set of experiences on which to base their reflections, their search for patterns and relationships, and their developing theories. In our example of the snails, the teacher focuses the children's attention first on description. But the next step might be to compare the snails' motion to that of an earthworm and a sow bug. This might be followed by observing their own movement and that of other familiar animals and a continuing discussion about similarities and differences and how movement relates to where an animal lives and how it gets its food. In contrast to this depth and breadth are experiences with phenomena such as magnets that are very engaging, but once children have noted what they do, there is little else to explore. With a range of experiences, children are more likely to be able to think about connections among them, question their naïve ideas, and develop new ones.

Equally important, the third criterion is that the phenomena, concepts, and topics must be engaging and interesting to the children AND their teachers.

While not a criterion for the selection of content for an individual unit, across a year, the science program should reflect a balance of life and physical science. For many reasons, teachers are more comfortable with the life sciences and steer away from physical science. This leaves out explorations of deep interest to children and deprives them of the challenges and excitement of experimentation. Inquiry into life science is different from inquiry into physical science, the former being more observational, taking place slowly over time. Inquiry in the physical sciences is more experimental with immediate results. Both are important, so it is balance that is important in an early childhood science program.

The Classroom

January 14: Water tables continue to be one of the favorite centers in the room. I love seeing how engaged the kids become filling cups, emptying cups, moving water from one compartment in the water table to another.

January 19: It was too cold for the kids to go outside today, so the kids in my small group did a clay project instead. The theme for the project was making things that can hold water. Tonya made a pot. Alex made a vase. Sam made a bowl. Ben made a pancake, then rolled it up. When I asked him what he was making, he said, “a pipe.” Tonya was quick to point out that pipes don’t hold water, but Ben didn’t care. The idea of making a pipe for water to go through, rather than a container for water to hold, captured his interest—and everyone else’s in the group, too. And suddenly, all the kids were making pipes!

January 20: The kids in my small group asked if they could keep making clay pipes today, so we did. It was Tonya’s idea to roll the clay around wooden cylinders, then remove the cylinders so that there is a hole for the water to move through, and everyone followed suit. After completing each pipe, they then told me where to attach it—watching very carefully to see if a hole needed to be bigger so that the water wouldn’t get stuck. They can really imagine how the water is going to move. Later Sam and Ben worked on making a long pipe. They wanted water to come out of both ends at once, so Sam suggested cutting a hole in the middle of the top so that they can add another pipe there. I asked him where that idea came from. He paused for a minute, and then said, “I was riding my bike really, really fast, and it made me think of water going down the pipe.” All of these pipes attached together are quite a sight. The kids have even given it a name—they call it “Water Town.”

January 31: During free choice, the kids continue to spend lots of time at the water table—using the tubes and T-connectors, exploring how water goes up and down and around the water wire wall. It’s almost as if the kids’ explorations at the water table are “feeding” their work with Water Town. At the same time, their work on Water Town feeds their work at the water table.

After all, it's at the water table where they can test out new ideas and possibilities that they can then bring back to Water Town.

Excerpts from Sue Steinsieck's Teacher's Journal (reprinted with permission)

There are many implications for the classroom given this view of science. Here I will briefly address science in the child-centered curriculum, the role of materials, the use of time and space, the key role of discussion and representation, and the teacher's role.

Science in the Child-Centered Curriculum

There are many definitions for "child-centered" curriculum that fall along a continuum. At one end is the belief that much of the curriculum is centered on the children's ideas and questions. It is co-constructed by the child and the teacher. At the other end is a structured program with little child input except during "free time." The reality of a good science curriculum is that it sits in between these extremes. The phenomena and the basic concepts are determined by the teacher, perhaps because of an interest she has observed in the classroom, but this need not be the case. Once a phenomenon is introduced and children begin their explorations, their questions may guide much of what follows.

From this perspective, the question to be asked is not, "Whose question is it?" but rather, "Are the children engaged?" Children need to own the content, but it need not necessarily be initiated by them. In the example above, water was the teacher's science focus. But the idea of pipes and Water Town clearly belonged to the children.

Materials for Science

The selection of and access to materials are critical to science. It is through the materials that children confront and manipulate the phenomenon in question. To the extent possible, the materials must be open ended, transparent, and selected because they allow children to focus on important aspects of the phenomenon. This is in contrast to materials that by their appearance and the ways in which they can be manipulated guide what children do and think. One example of the difference is the prefabricated marble run. Rather than creating their own roadway for marbles and struggling to make it work, the marble run has done the thinking for the children. All they need to do is drop the marble in and watch it roll. This is very different from using blocks and some form of gutter materials where they need to grapple with the slope, the corners, the intersection of the parts, and solve the problem of getting the marble to reach their finish line. Another example is the use of transparent tubing, droppers, and funnels in the water exploration as described in the teacher's journal above. The materials themselves are open ended, and the movement of water visible. A third example is the use of multiple kinds of blocks and construction materials when investigating structures. In such an investigation, Legos might be temporarily removed because the fact that they snap together reduces the challenge of building towers and walls and thus reduces the focus on the forces at work.

Time and Space for Science

Good science investigations take place over extended time, both short term and long term. Engaged children may stay with something for significant periods of time, and some children may need time to get involved. The typical schedule in the classrooms of young children often militates against inquiry-based science learning. Short 20- or 30-minute activity or choice times allow children to start but not continue their work. In addition, if science work is episodic and not available regularly during the week, continuity is lost and the opportunity to draw conclusions reduced. Science also needs to be talked about and documented. This, too, takes time. Science needs space. If children are to engage with phenomena in many different ways, activity may need to be spread out in the classroom and outdoors. Building structures may happen in the block area, on table tops, in the sand table. Germinating seeds need to be put somewhere, as do plants that are growing in other ways and interesting collections from outdoors. An investigation of shadows might include a shadow puppet theater, a darkened alcove for playing with flashlights, and a lamp and screen to explore shapes. The implication of this need for space and time is that focusing on a science study may require that other things be set aside or changed. The morning circle routine might become a science talk a couple of time a week. The dramatic play corner might be a shadow puppet theater, and the water table might be closed to dish washing and baby doll bathing.

Discussion and Representation in Science

Discussion and representation are both critical to science learning and an important part of the inquiry process and the development of science reasoning. Both in small groups and in large ones, discussion encourages children to think about what they have experienced, listen to the experiences of others, and reflect on their ideas. Similarly, representation using a variety of media—including drawing, writing, and collage—encourages children to observe closely and reflect on their experiences over time as well as build vocabulary and language structures. George Forman, emeritus professor at the University of Massachusetts, in an unpublished comment says it this way, “Experience is not the best teacher. It sounds like heresy, but when you think about it, it’s reflection on experience that makes it educational” (Conference presentation).

The Teacher’s Role

The teacher’s role is critical to children’s science learning, and it is a complex one that is informed by her knowledge of children, of teaching and learning, and of pedagogical science knowledge. I want to highlight just one of these—pedagogical science knowledge. Children’s scientific inquiry is guided by the teacher’s explicit understanding of the important underlying science concepts of the focus she has chosen. For example, the children’s work with water in the teacher journal above is indeed about pipes and “Water Town,” but it is also about how water flows—a basic property of liquids. While explicit teaching of the concept is not appropriate, the structure of the experiences and the teacher’s facilitation is guided by her understanding of the concepts and how children learn them. Her questions, comments, and probes draw the children’s attention to the concept—in this case, that water flows and flows down. In the study of snails, described earlier, the children were interested in lots of things—whether snails liked each other, how they had babies, how they got in their shells. In the notes, we see the teacher picking up on one of those interests and a basic characteristic of animal behavior and adaptation—how they move. This kind of teacher guidance and facilitation is based in each teacher’s understanding of the concepts behind the children’s work and enables her to encourage children to notice and reflect on key aspects of the phenomenon they are exploring.

Conclusion

For many years, the role of early childhood education has been focused on children's social, emotional, and physical development as well as very basic skills in language and arithmetic. Although work with materials is fundamental to early childhood, focusing children's thinking on the science of these experiences is rare. Science activities often are seen as vehicles for the development of vocabulary and skills such as small motor coordination, counting, and color and shape recognition. These activities are not parts of long-term explorations or sequenced into projects focused on the science concepts and emphasizing the processes of scientific inquiry. This is exacerbated when teachers are uncomfortable with science, have little science background, and lack confidence in their abilities to teach science to children.

In many settings, the new knowledge about children's cognitive potential is not being used to broaden and deepen the science curriculum to include more in-depth and challenging experiences. Instead, the increasing concern about reading has reinforced the almost singular focus on learning basic skills of literacy, numeracy, and socialization. It also is bringing to the early childhood setting increased pressure for accountability, leaving little room for children's rich play and exploration of the world around them.

The exploration of the natural world is the stuff of childhood. Science, when viewed as a process of constructing understanding and developing ideas, is a natural focus in the early childhood program. As described here, children's inquiry into appropriate phenomena is not only the place to build foundational experiences for later science learning, it is fertile ground for the development of many cognitive skills. It also is a context in which children can develop and practice many basic skills of literacy and mathematics. Finally, science is a collaborative endeavor in which working together and discussing ideas are central to the practice.

Acknowledgments

This paper draws from work done in collaboration with Ingrid Chalufour, Cindy Hoisington, and Jeff Winokur, which resulted in the publication of the Young Scientist Series (Chalufour & Worth, 2003, 2004, 2005) and *Worms, Shadows, and Whirlpools* (Worth & Grollman, 2003).

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