CHAPTER 4

The Power of Children's Thinking
by Karen Worth

The earth is flat. Fluttering leaves make the wind. The moon follows you as you walk. Based on how they understand everyday sensations and experiences, even young children create theories to explain the world around them. As this essay points out, guiding children to discover a more scientific view of the world means helping them learn through those same sensations and experiences—something that inquiry does particularly well.

Two grandparents were out walking with their young grandchildren. They came to a rabbit hutch with three rabbits inside, an adult male and female, and what seemed to be a baby. As the children watched, a leaf fell on top of the cage. The female rabbit reached up, pulled the leaf into the cage, and dropped it on the ground. At that moment, one of the other rabbits started to eat it. Four-year-old Tommy, the littlest child, was intrigued. He picked up some leaves, put them on top of the cage, and watched the rabbit pull them inside.

When they got home the grandmother asked, "Well, what did you think of those rabbits? What do you think was going on in that cage?" Tommy said, "The mommy rabbit taught us something when she pulled those leaves down. The mommy rabbit was really a teacher and you and grandfather and the other rabbits, we were all the students."

There are many stories in which children reveal their attempts to make sense of the world. They are important, not because they are cute, but because they tell us something about the power of children's thinking.

Young children can and do inquire, and it is important not to underestimate the power of this inquiry. They do so in different ways, depending on developmental level, prior experience, and context. From what we know from cognitive research, the context has to be concrete; the phenomena and objects must be ones children can explore with their senses. But at all ages, children do observe and investigate, collect data, think, reason, and draw conclusions.

Children are natural scientists. They do what scientists do, but perhaps for some slightly different and less conscious reasons. They are anxious to understand the world just as adults are. There is a terribly interesting, but rather confusing, world full of stimuli all around them. Many adults, however, have learned to ignore some of that world rather than investigate it. Young children ignore very little. They are very curious; they ask questions constantly. They are willing to look and to inquire about the world. This is not the idealized world of scientific theories, principles, and models, nor is it the precise world of the laboratory. Children draw their understanding from the messy world around them. As a result, it's a messy exploration, and it takes place within the context of the child: the child's frame of reference, his or her prior experience and developmental stage, and the adults around that child.

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As they explore, children organize what's around them, building their own schemes and structures and conceptions. We have lots of research as well as anecdotal evidence of this. The child who visits another country, sees a half-moon there, and decides that the other half must still be back home has a pretty interesting idea of what the moon is all about. The 3-year-old watching the fluttering leaves on a tree decides that the movement of the leaves is what makes the wind. This is, of course, a very natural and logical explanation for a phenomenon that the child has experienced often, yet cannot touch or manipulate.

The theories children build, whether they are right or wrong, are not capricious. They are often logical and rational, and firmly based in evidence and experience. The experience may not be deep and broad enough, the thinking capability may not be enough to formulate what we call a scientific theory, but the process by which the children form these ideas is very scientific indeed. Some call these early ideas children form misconceptions; others label them naive conceptions, or alternative conceptions. They are simply the children's conceptions and do not deserve the negative connotations associated with these terms. We all try to organize and structure the world around us; we do it on the basis of what we have available to use. We don't wait to be told. We don't take it all in equally. We try to figure it out. I believe that it is the same thing for young children. It is a kind of common sense—2-year-old common sense, or 50-year-old common sense, it doesn't matter.

For young children, this organization and structuring is very personal and has certain characteristics. Children tend to be centered on themselves and heavily reliant on the immediate context and the data of their senses. Their thinking is perceptually dominated, drawn from direct experiences, rather than conceptually dominated. It is difficult for them to step outside themselves and to look at the world beyond them. The idea that the moon follows you as you walk through the streets, for instance, is very common for the 4-, 5-, or 6-year-old. The notion that the earth is flat and the sun moves around us are other common understandings among older children. The immediate context is all that they have, tightly linked to personal experience. But the ideas that they develop are, in the right context, transferable across experiences, as were 4-year-old Tommy's when he applied his idea of teacher and pupil from his experiences of school to the rabbits.

Young children are often more linear in their thinking about causality than adults are. It's hard for them to juggle too many factors at the same time. They are not terribly upset, in the primary years, if theories contradict one another. They can have one theory over here and another one over there, and that's okay, for the moment. They haven't quite taken hold of the notion that you can't have contradictions. It doesn't necessarily mean that their thinking is illogical or irrational. It may simply mean that they do not need consistency or see the connections. Nor do young children tend to value parsimony, or elegance and simplicity of explanation. They may have very complicated explanations of how and why something happens. They may not care whether it is as elegant or simple as it could be. Simplicity is a more adult constraint on theory formation, not necessarily one of young children.

Another characteristic of children's thinking is tenacity. Children do not want to give up the concepts and theories they work so hard to make. They take their experiences and struggle to come up with understandings that work in their daily lives. They are not about to drop their ideas just because someone says so, or because an event disproves what they have come to believe. As anyone familiar with the history of science can attest, even adults have trouble changing theories that are well grounded in experience. If a child's theory works, if it has been productive and the child has worked hard to build that theory, she will not give it up unless she has a lot of new experiences that provide reasons to do so.

When we look at very young children before they have had the structures and rules of formal schooling imposed upon their learning, or when we see them in informal settings such as museums, playgrounds, and parks, we see a spontaneously driven activity to make sense of the world through observation, investigation, and social interaction. But children working by themselves are not going to learn everything they need to know. There is a clear role for teaching and for structured settings. To define those settings and the nature of the teaching, we need to add an understanding of the goal and content of science education to our understanding of children's learning.

The goal of science education, as stated in the *National Science Education Standards*, is "to educate students who are able to experience the richness and excitement of knowing about and experiencing the natural world; use appropriate scientific principles in making personal decisions; engage intelligently in public discourse and debate about matters of scientific and technological concern; and increase their economic productivity through the use of the knowledge, understanding, and skills of the scientifically literate person in their careers" (p. 13).

The *Standards* also describe the subject matter content of science education—the knowledge and understanding students must acquire. They state that "scientific knowledge refers to facts, concepts, principles, laws, theories and models," and understanding science is described as the "integration of a complex structure of many types of knowledge, including the ideas of science, relationships between ideas, reasons for these relationships, ways to use the ideas to explain and predict other natural phenomena, and ways to apply them to many events" (p. 23). The *Standards* also describe the understanding of and ability to do scientific inquiry as a critical component of the content of science education, defining inquiry as "the diverse ways in which scientists study the natural world and propose explanations based in the evidence derived from their work" (p. 23). Inquiry also refers to the "activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (p. 23).

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With this view of learning, goals, and content, we can begin to construct our understanding of inquiry-based science teaching. Fundamental to this kind of teaching and learning is the willingness to work with children "where they are," and to understand with what they are struggling. In his book *Informed Vision* (1974: Agathon Press), David Hawkins, philosopher of science and director of the Elementary Science Study (ESS) during the 1960s, has said that we must try to understand "the map" of children's minds. There are some interesting studies, for instance, on whether children think the earth is round. If they look outside, they see a flat world. But they also know that the world is round because they have heard it, and seen it in the movies and on TV. There are studies of first graders and second graders who will say, yes, the earth is round. But their image of "round" is the shape of a pancake, not the round sphere that adults speak of. Slightly older students may produce an image of an earth that is definitely round, but may see themselves inside it. They imagine that they live on a flat surface inside some kind of sphere. They are struggling with some very basic concepts—up is up and down is down, but the earth is a round something in space. It is up-down and flat, and yet round. The students are trying to reconcile what they "know" with the round world about which they are learning, and they have wonderful ways of doing that.

It is not always easy to see what a child is struggling with. We may be teaching them all about the planetary system, while they are still struggling with whether the world is round or flat and what that means. By offering children open-ended experiences and discussion, and by carefully observing and listening, we can come closer to knowing not only what their conceptions are, but the source of their struggle. If we don't, they may draw a picture of a round world, but not believe or understand what that really means.

To help children move toward better understanding and more powerful constructs than the ones they can make by themselves, we create classroom opportunities that are designed to allow children to approach learning much as they do when they confront materials and phenomena in unstructured settings. But we provide much more: focus, structure, breadth, and dialogue.

As children explore phenomena and materials, they focus on what is immediately important to them, not necessarily on what is important from a scientific point of view. Structured programs in a school environment make the phenomena and objects somewhat less messy and encourage students to look more closely at particular elements of what is going on. Teachers also guide children's inquiry to help them be more orderly and systematic than they might be on their own, and so they can draw on other resources such as books, people, media, and technology.

Children's early conceptions arise from their experiences, which are limited by time and circumstance. In school, teachers can select a range of experiences that provide children with new data and encourage them to challenge their existing ideas and build new ones. School also provides the opportunity for children to learn how to record what they are doing in many different ways, how to communicate and share with others, and also how to develop models for understanding as they get older. In school, children can also work with and learn from one another.

In the best of good science teaching, the role of the teacher is crucial no matter how good the curriculum materials are. To support children's learning in science, teachers must be willing to try to understand the ideas and formulations children have made and are making and to guide their instruction accordingly. This means the teacher accepts and supports a wide variety of views and encourages real dialogue and debate among the children. This also means creating a rich physical and social learning environment in which new questions, explorations, and investigations can arise, and in which every step is not dictated. In such an environment, the teacher allows the children to gather data and approach ideas from multiple contexts. He or she allows the children time for trials, repetition, and mistakes, and creates a balance between adult guidance and time for children to be guided by their own questions, predictions, and explorations.

Children need these experiences in both formal and informal settings. We can give them information, demonstrations, books, and step-by-step experiments, but these cannot replace the kinds of experiences they need to develop tenacious and deep understanding. If children are struggling with an idea, they need time to come to a physical understanding of it before they can really use it in their world. If they do not have these opportunities, they may learn the words and information they need for school. They may get all the answers right on a test. And they may also create another kind of understanding on their own. They may come to believe that there is something called "science," in which they are told what to see, what to know, and what to think, and that it is rather unrelated to the world they experience outside of school. They may doubt their experimental abilities when the "results" they are told to expect are not necessarily what they really do see. They also may come to the conclusion that there is a whole realm of knowledge that they themselves cannot understand, and that they must simply take, unquestioned and not understood, the facts as given from an adult or a textbook.

Alternatively, if we accept the challenge of the *National Science Education Standards* and use what we know from research and practice, we can provide environments in which teachers are teaching through inquiry. When children have the opportunity to cultivate their own skills and construct their own ideas and concepts, then they can develop an understanding of the world that is deep and real, and begin to enjoy, understand, predict, and generate new knowledge on their own.