PRESCHOOL PATHWAYS TO SCIENCE

PrePS™

FACILITATING SCIENTIFIC WAYS OF THINKING, TALKING, DOING, AND UNDERSTANDING

ROCHEL GELMAN
KIMBERLY BRENNEMAN
GAY MACDONALD
MOISÉS ROMÁN

PRESCHOOL PATHWAYS TO SCIENCE

PrePS™

FACILITATING SCIENTIFIC WAYS OF THINKING, TALKING, DOING, AND UNDERSTANDING

by

Rochel Gelman, Ph.D.
Kimberly Brenneman, Ph.D.
Rutgers University
Piscataway, New Jersey

Gay Macdonald, Ph.D.
UCLA Early Care and Education, Krieger Center
Los Angeles

Moisés Román, M.A.
UCLA Early Care and Education, University Village Center
Los Angeles

PAUL H. BROOKES PUBLISHING CO.®

Baltimore • London • Sydney

· P A U L · H ·
BROOKES
PUBLISHING CO.®

Paul H. Brookes Publishing Co.
Post Office Box 10624
Baltimore, Maryland 21285-0624
USA

www.brookespublishing.com

Book design by Mindy Dunn.
Typeset by Integrated Publishing Solutions, Grand Rapids, Michigan.
Manufactured in the United States of America by Versa Press, Inc., East Peoria, Illinois.

The individuals described in this book are composites or real people whose situations are masked and are based on the authors' experiences. In all instances, names and identifying details have been changed to protect confidentiality.

The photographs in this book are printed with permission of the individuals pictured or of their parent(s) or legal guardian(s).

Library of Congress Cataloging-in-Publication Data

Gelman, Rochel.
Preschool pathways to science : facilitating scientific ways of thinking, talking, doing, and understanding / by Rochel Gelman, Kimberly Brenneman, Gay Macdonald.
p. cm.
Includes bibliographical references and index.
ISBN-13: 978-1-59857-044-1 (pbk.)
ISBN-10: 1-59857-044-7
1. Science—Study and teaching (Preschool) 2. Education, Preschool—Activity programs. I. Brenneman, Kimberly. II. Macdonald, Gay. III. Title.
LB1140.5.S35G45 2010
371.3′5–dc22 2009024084

British Library Cataloguing in Publication data are available from the British Library.

2013 2012 2011 2010 2009
10 9 8 7 6 5 4 3 2 1

Contents

List of Figures, Tables, Boxes, and Activities

About the Authors

Rochel Gelman, Ph.D., Professor and Co-Director, Rutgers Center for Cognitive Science and Department of Psychology, 152 Frelinghuysen Road, Piscataway, NJ 08854-8020

Rochel Gelman is a professor of Psychology and Cognitive Science, and the co-director of the Rutgers Center for Cognitive Science (RuCCS). Before joining Rutgers, she was Professor of Psychology first at the University of Pennsylvania and then at the University of California–Los Angeles (UCLA). She is widely known for her pioneering research on what infants and preschool children already know or learn with relative ease. She is a member of the National Academy of Sciences and the American Academy of Arts and Sciences; a William James Fellow of the Association for Psychological Science; and a recipient of the Society for Research in Child Development's Distinguished Lifetime Scientific Contribution to Child Development Award, the Early Career Research Contribution Award, and the Distinguished Scientific Contribution Award of the American Psychological Association. She has received a Mentor Award from Division 7 of the American Psychological Association for her training of other scientists, especially women who have gone on to distinguished careers in psychological research.

Dr. Gelman's research program is organized around a longtime interest in learning, cognition, and developmental cognitive science. Her book, *The Child's Understanding of Number* (Harvard University Press, 1978), with C.R. Gallistel, is considered a landmark publication about preschool children's numerical competencies. Dr. Gelman's other publications include several edited volumes and monographs and more than 100 book chapters and papers. She has collaborated with school and museum professionals in published research on the creation of environments that promote math and science learning in schools and museums. *Preschool Pathways to Science (PrePS™)* represents her most extensive effort of this kind.

Kimberly Brenneman, Ph.D., Assistant Research Professor of Psychology; Professor of Cognitive Development, Rutgers Center for Cognitive Science and Department of Psychology, 152 Frelinghuysen Road, Piscataway, NJ 08854-8020

Kimberly Brenneman is an assistant research professor in the Department of Psychology at Rutgers University. She is also affiliated with the National Institute for Early Education Research (NIEER). In addition to her work on the development, implementation, and assessment of PrePS, Dr. Brenneman's basic research interests include young children's scientific reasoning, their understanding of the relationship between form and function, their comprehension and production of notations, and their understanding of the animate–inanimate distinction. Her work at NIEER focuses on ways to improve the instructional practices that support science and mathematics learning in preschool classrooms. Dr. Brenneman is a regular presenter at national professional conferences, has published a number of research articles, and has served as a board member for multiple community education organizations. She is also an educational consultant to *Sid the Science Kid,* the PBS Kids animated series and web site (produced by KCET/The Jim Henson Company). *Preschool Pathways to Science* is her first book.

Gay Macdonald, Ph.D., Executive Director, UCLA Early Care and Education, Krieger Center, Box 951785, Los Angeles, CA 90095-1785

Gay Macdonald has served as the executive director of UCLA Early Care and Education (ECE) since 1991. She came to this position as a highly experienced and respected child care professional in the Los Angeles community and currently serves on the County of Los Angeles Child Care Planning Committee; she was previously co-chair of the Curriculum Task Team for Los Angeles Universal Preschool. While responsible for the operation of three child care centers at UCLA accredited by the National Association for the Education of Young Children and licensed to serve 340 children ages 2 months to 6 years, Dr. Macdonald always sought ways to expand UCLA's influence in the area of early childhood education throughout the Los Angeles community. Together with the Gelman Cognitive Development Lab, she developed the *Preschool Pathways to Science* program as the integrative focus for all aspects of the ECE program, an innovative approach to providing the highest quality child care for UCLA faculty, staff, and students and a model for the broader community.

Moisés Román, M.A., Director, UCLA Early Care and Education, University Village Center, Box 951785, Los Angeles, CA 90095-1785

Moisés Román is the director of the UCLA Early Care and Education University Village Center. Prior to that assignment, he served as the curriculum coordinator for the department, overseeing the implementation of the science-based curriculum, *Preschool Pathways to Science,* in 19 classrooms and conducting teacher training for all three ECE centers at UCLA. He is an advocate for early childhood education, both for children and for teachers and professionals in the field, and conducts workshops at national, state, and local conferences, presenting a variety of topics such as Science for Young Children, Teachers Matter, Men in Education, the Development of Early Literacy, and many more. Mr. Román also serves as educational consultant to KCET television's award-winning series, *A Place of Our Own/Los Niños en Su Casa,* and to KCET/Jim Henson Company's award-winning PBS Kids series, *Sid the Science Kid.*

Acknowledgments

Preschool Pathways to Science (PrePS™) has been a long time coming—nearly twenty years. It started when NASA approached Gay Macdonald (Executive Director of the sites of the UCLA Early Care and Education [ECE]) with a request to help develop science-learning opportunities for a preschool program serving families at an Air Force base located north of Los Angeles. Gay turned to me, as a member of her advisory board and a student of young children's scientific inclinations. The preparation of the proposal for needed funds was greatly facilitated by the advice I received from my former colleagues at the University of Pennsylvania: Drs. Christine Massey and Pamela Freyd, who had embarked on a related project for kindergarten to Grade 3. Funds in hand, we started. We never anticipated as long a gestation period as proved to be necessary. As a result, we have benefited from the involvement of a very large number of people and schools, teachers, teacher aides, undergraduate and graduate research assistants, and, most especially, the children and their parents or guardians. We are grateful to each and every one of them. Some individuals or groups were critical players in the creation of PrePS. I am deeply grateful for the privilege to work with all of the following individuals:

- Lisa Travis and Earl Williams (members of my lab at UCLA), and Susan Woods (a UCLA teacher), served as project coordinators during the initial years of grant funding from National Aeronautics and Space Administration (NASA; Grant NCC-2826) and the National Science Foundation (NSF; Grant REC-0529579). All understood that the program involved a mind-set shift for the teachers. It was especially important that Susan Wood "got it" from the start and helped other teachers come online. She also worked with Osnat Zur to bring out her children's numerical competence as well as to brainstorm about PrePS. Eventually, Zur filled the same role in meetings with groups of teachers.

- Amy Aguayo, Shabazza Higaro, Jennifer Murillo, Moisés Román, Juanita Salter, Sofia Silva, Fariden Shabanarfar, and Geraldo Soto (all of UCLA ECE) and, again, Lisa Travis, Earl Williams, as well as Osnat Zur, Beth Lavin, Stephanie Reich, and Girlie Delacroix (all at UCLA), showed us some of the many ways that teachers and researchers could work with PrePS at its site of origin. The form of the collaboration that emerged facilitated a related researcher–teacher role as well as the curriculum.

- Ines Louro and Marta Paris (who served as teacher-researchers); Johanna Jandrisovits and Jennifer Manuola (Directors of the Douglass Child Study Center at

Rutgers); Marilyn Valentine (Director, Livingston Avenue Child Development Center); Connie Penn (Director, The Children's Corner)—all based in the New Brunswick, New Jersey area; and Samantha Bundy, Jennifer Cooper, Lindsay Downs, Beth Lavin (who moved to Rutgers), Jaimie Liberty, Kristina Metz, and Irene Nayfeld—members of my lab, all served as key players in the effort to embed PrePS in new schools, including ones serving inner-city families, most of whom were Spanish-speaking.

This creative effort, as well as the preparation of the book, was funded mainly by NSF Grant SBR-9720410. The authors are solely responsible for the opinions and content contained in this book. In no way does our grant support carry an endorsement from the funding agencies.

I now turn to my co-authors. It is hard to imagine anyone who could substitute for Gay Macdonald, Executive Director of the several UCLA ECE sites. She understood immediately that we were taking on a hard task. Still, she put her full trust in me, probably knowing that this would draw me in as it did. This is but one sign of why Gay is a brilliant leader and mentor. Early on in our work, she identified the then very young Moisés Román as a winner. He became a key member of the conceptual team in very short order. Both Gay and Moisés have served as editors, reviewers, and rewriters throughout the preparation of this book. At every step of the way, Kimberly Brenneman has been a fantastic colleague and friend as well as an unbelievably fine collaborator. We became close to one mind as the book took final shape. This was very much facilitated by Kim's role as project organizer—and thus overseer—of the successful effort to move PrePS from its development to its implementation into ongoing programs, including programs for children from different economic strata. As a result, we learned a great deal about how to help teachers get started with and then continue to use PrePS. What a wonderful team of authors! Thank you. Thank you.

Rochel Gelman
July 2009

In memory of
Ann L. Brown

1

Introduction to PrePS™

Young children can demonstrate surprisingly abstract abilities, as did Dara (3 years 11 months) who denied that a puppet could remember but allowed that a cat could. When asked why, she answered, "because all the things that are alive can remember." In a related way, when 3- and 4-year-olds were shown photographs of a statue that had human-like features, they said that it could not go up and down a hill by itself. In contrast, they accurately judged that an echidna, an animal they had never seen or heard about, could move by itself. When asked to explain, children said that the statue was "just a furniture-animal," that it did not have "real" feet, or that it was "too shiny." However, they said the echidna, which looked more like a cactus than any familiar animal, could move by itself "because it had feet"—even though these were under the echidna and not visible.

These vignettes are consistent with the growing research base that shows that young children, including infants, can treat the difference between animate and inanimate objects in an abstract way (e.g., Gelman & Opfer, 2002; Saxe, Tzelnic, & Carey, 2007) and shows children reaching inferences on the basis of high-level knowledge. Indeed, the book *Eager to Learn* (Bowman, Donovan, & Burns, 2001) summarizes the evidence as follows:

> [There] appear to be "privileged domains" [of learning], that is, domains in which children have a natural proclivity to learn, experiment and explore . . . [T]hey allow for nurturing and extending the boundaries of the learning in which children are already actively engaged. (p. 9)

Reports from the National Academy of Science (Duschl, Schweingruber, & Shouse, 2006) the National Science Board (2009), and various private foundations concur: Science learning opportunities should be strengthened in early education. The Bowman et al. (2001) report details efforts to uncover what preschool children can do in the realm of abstract thinking as opposed to what they cannot do. The "can-do" research base is the bedrock of our program—Preschool Pathways to Science (PrePS™)—and informs our design of appropriate science-learning opportunities for preschool children.

These research and policy developments present a challenge to educators committed to assumptions of traditional stage theories, which characterize young children as being perception-bound and unable to engage in abstract thinking. Many educators, therefore, may believe that young children do not benefit from classroom opportunities that ask them to engage in abstract thinking and are best served when given materials for their own hands-on exploratory play (Elkind, 1989).

It is true that preschoolers—as well as elementary and high school students, and even some adults—are not ready to assimilate certain aspects of science and math. For example, lessons about the Newtonian principles of physics and the biochemistry of diseases do not guarantee learning on the part of college students (e.g., McCloskey, Washburn, & Felch, 1983). However, preschoolers can understand or learn about some areas of science with relative ease. As discussed in the Bowman et al. (2001) report, science-learning opportunities fit well with children's active tendencies to explore, seek information, and try out different ways to use materials. Furthermore, learning how to do science also provides literacy and arithmetic experiences.

SCIENCE FOR PRESCHOOL?

Some people may think that we are being overly optimistic about the abilities of preschool children. After all, traditional stage theory continues to be taught to future educators. Piaget (1970), Vygotsky (1962), and Bruner (1964) all share the view that young children are perception-bound and lack the mental structures needed to interpret abstract relations. Because of a dependence on the "here and now," children do not use consistent criteria on classification tasks, fail conservation of number and volume tasks, engage in precausal reasoning, and often rely on their own egocentric perspective to judge the perspectives of others. Even when children in the early elementary grades progress to Piaget's stage of concrete operations and begin to sort objects according to a consistent set of logical criteria and to systematically rank-order objects with different lengths, they still are characterized as lacking the basic cognitive capacity to understand the methods and content of science (Inhelder & Piaget, 1964). Vygotsky (1962) concluded that children could not engage in scientific reasoning until they are about 10–12 years old.

There are reliable research findings to support the stage theorists' assumptions for the preschool years. Piaget's liquid conservation experiment provides a compelling example. Four-year-olds almost always fail the Piagetian conservation test. Even though they watch as the water in one of two identical glasses of water is poured into a taller and thinner glass, they assert that the resulting amounts are no longer equal. They justify their nonconserving answer by saying that there is more in the tall column of water. When the water in the tall column is returned to its original glass, children assert that there now is the same amount of water as there was to start. Older children conserve the original amount as it is transferred to the glass with different dimensions. This is an especially salient example of how preschool children can be captured by the perceptual here and now. There are many others (Gelman & Baillargeon, 1983).

Given that there are ample demonstrations of young children being misled by the surface characteristics of objects, people might reasonably ask, "Why develop a preschool program about science?" Our answer is that young children are "scientists-in-waiting." They are naturally curious and actively involved in exploring the world around them. More to the point, they can and do develop abstract concepts in domains that fall within the content of science. As illustrated above, young children are well along in their learning about the animate-inanimate distinction. In

PrePS we link conceptual accomplishments like these to the development of process skills that are important for science, including *observing, comparing and contrasting, measuring, predicting, checking, recording,* and *reporting*. Classroom teachers serve a key role in modeling, guiding, and supporting these skills for young children. We will further explore the value of PrePS for children and their teachers in the remainder of this chapter and throughout the book.

MORE COMPETENCE THAN MEETS THE EYE

We are fortunate to work in a time when the preschool mind is celebrated for what it can do rather than what it cannot do. Preschoolers were once thought to be conceptually limited, but research has since demonstrated that they are able to think and talk about many science-related topics (Carey, 2009; Gopnik & Schulz, 2007).

When children are provided with opportunities to further develop a knowledge base they know something about already, they can perform in rather sophisticated ways. For example, Novak and Gowin (1984) reported that some second-grade students who participated in an elementary science tutorial program achieved a better grasp of the particulate nature of matter than did some 12th-grade students. These researchers concluded that schools were failing to take advantage of young children's science-learning capacity. We agree and submit that the same is true for even younger children.

You may already know that some preschoolers are dinosaur experts and can name an impressive number of dinosaurs. When certain children encounter a picture of a novel dinosaur, they may even be able to tell you what it ate and where it lived. As Gobbo and Chi (1986) demonstrated, these budding young experts organize their knowledge in this domain in a hierarchical fashion. When children observe that a dinosaur has large, sharp teeth, they then infer that the animal is a carnivore—and even use the technical term *carnivore*. A related demonstration comes from some children's motivation to learn about Pokémon characters, so much so that they know more than their parents about the interrelationships and features of the characters (Lavin, Galotti, & Gelman, 2003).

A new generation of cognitive developmental researchers has embraced the idea that preschoolers' concepts are often more advanced than previously believed (see Chapter 2). This has led to a major focus on identifying preschoolers' conceptual competence. There is an ever-growing body of evidence that preschool children actively build a knowledge system around the principled distinction between animate and inanimate objects and related concepts of causality. For example, when asked what is inside a doll, an animal, and a person, a very large majority of 3-year-old children provide fundamentally different answers for each kind of object: The doll has stuff, batteries, or even air inside, whereas animals and people (Gelman, 1990; Gottfried & Gelman, 2004) have blood, bones, food, and even *character* (what a 5-year-old child volunteered to Brenneman) on their insides. Results like these contributed to our decision to develop PrePS. The difference between animate and inanimate objects and their differential conditions for motion and change are foundational for science. In addition, the animate-inanimate findings provide powerful evidence that young children can make inductions from what is known to what is not known, to think about the unseen, and to organize knowledge into hierarchical structures.

Other similar sets of findings about preschool conceptual competence contributed to the decision to develop PrePS.

We know now, for example, that preschool-age children can reason about cause and effect. An early study by Bullock and Gelman (1979) showed that children make reasonable choices about potential causes and assume that causes precede effects. This is but one result that contradicts Piaget's (1930) view that young children are precausal because they lack an assumption of mechanism, confuse the order of cause and effect, and attribute animate powers to all objects. For example, Laura Schulz and Elizabeth Bonawitz (2007) found that preschoolers are motivated to seek explanations through exploration. Under normal circumstances, preschoolers will stop playing with an old toy when a novel one is offered. In the Schulz and Bonawitz work, preschoolers did just this when the mechanism that made the toy work was clear to them. When this mechanism was not understood, however, children tended to ignore the second toy and continue to explore the first toy until they figured out how the toy worked. The simple presence of a new toy did not outweigh their motivation to reach closure on their goal to understand. This example illustrates an important characteristic of young children. They are motivated to continue to repeat an activity or to ask questions until they get the information they are seeking (Chouinard, 2007). Somehow they monitor their own knowledge and continue to explore, providing repeated evidence that the young mind is, indeed, active and engaged.

Given the ever-growing research base about preschoolers' competence, we set out to determine how to leverage children's spontaneous explorations and knowledge-seeking activities about some science concepts to create a program to support preschool science learning. Why resist the opportunity to move children onto relevant learning paths for science? Some preschool educators may offer an answer to this question: They were not required to study science and do not feel prepared to teach it. Nor are they eager to add yet another set of activities to their already full agendas.

Many teachers are concerned about their ability to teach science. However, because the science used in PrePS is based on what has been learned about preschool minds, the selected topics are not examples of a pushdown curriculum from physics, chemistry, or microbiology. Teachers will also find that they can embed some aspects of PrePS into what they are doing without much additional effort. They will be able to use science to encourage children to ask questions, solve problems, communicate and pay attention to detail, record observations and predictions, learn the terms that describe their observations, and use these terms across lessons. For us, the best evidence that preschool teachers can work with and benefit from PrePS is that many come to realize that they do know a lot about the science and, like their children, are eager to learn more.

A PREVIEW OF PrePS

PrePS encourages science-based learning through activities and experiences that allow children to explore big ideas in depth and to learn the practices and language of science. The program was designed to enhance the classroom experience for both teachers and children. Preschool teachers, directors, and cognitive researchers collaborated with the goal of fostering enthusiasm, fresh perspectives, and feelings of competence in the classroom. From the teacher's point of view, PrePS can ease the typical workload by encouraging collaboration and connecting daily lesson plans.

We are determined to feed the curiosity of young children and capitalize on their tendencies to actively explore their social and physical worlds. Therefore, PrePS makes a special effort to develop children's observational skills for purposes of obtaining information in a reliable way—through their own observations and explorations of the world but also through discussions with classmates and teachers and by engaging in simple experiments. The program also features teachers' support of children's tendencies to ask questions and make predictions about topics related to science. We want children to learn that a question might have more than one answer. Most important, PrePS is a program that places the development of scientific processes in the context of the need to develop connections between concepts and the related vocabulary across learning experiences throughout the year. Children are encouraged to draw connections between activities, ideas, and vocabulary; to link questions and solutions from one activity to another; and to understand and relate transformations and sequences that unfold over time, as in the case of plant and animal life cycles.

PrePS teachers connect learning experiences throughout the school year based on a key principle of learning: It is always easier to learn something that one already knows something about than to start from scratch (Bransford, Brown, & Cocking, 1999; Gelman & Lucariello, 2002; Resnick, 1987). This principle applies to all learners, especially young ones. For example, a 4-year-old boy went to a science program for young children at the Franklin Institute in Philadelphia. When asked what he learned at program, the child replied, "I learned when they evacuated a tube, things fell together." No amount of questioning elicited another answer. But later in middle school, the boy related what he learned in school that day by tying it to his memory from preschool: "Remember when I went to the Franklin Institute and we evacuated that tube? Well, now I know what that was all about." It is our hope that your students will learn enough to make comparable connections at a later point in their education. The goal is to put the children on relevant learning paths that will provide more and more relevant data for constructing coherent understandings.

PrePS allows teachers to systematically plan their curricula and set specific, attainable learning goals for their students. Teachers can guide children in organized investigations of the everyday world, thus promoting scientific skills such as observing, predicting, checking, measuring, comparing, recording, and explaining. Although subsequent chapters in this book provide examples of how we have introduced these activities, it is important to realize that PrePS is not a set curriculum with fixed units that must be taught in sequence, or a list of unrelated facts and terms that children must master. Rather, PrePS is an approach that relies on the natural curiosity and flexibility of preschool children and teachers.

When implementing PrePS, you will not be asked to prepare seat-work. You will not encounter a pushdown curriculum that is made up of bits and pieces of what is found in textbooks for much older students, nor will you be put in the position of simply teaching children to memorize facts and words. Programs that offer pushdown ideas for science activities often require that learners already have sophisticated levels of background knowledge. Although young children can observe such things as the shape of the moon, they cannot be expected to understand why the moon changes shape, its 28-day cycle, its effect on the tides, or why people would weigh less if they were on the moon.

With PrePS, you will be embedding appropriate key content and science practices across the curriculum. You will be able to take advantage of the fact that concepts do not stand alone, each separate from the other. In this way, you can build sequences of learning experiences that help children construct conceptually coherent domains of knowledge about particular science topics. For example, consider the concept of *animal*. Such a thing moves by itself, breathes, eats, reproduces, and grows. Many of the same terms can be applied to trees and other plants; however, plants cannot move around by themselves and do not obtain nourishment in the same way as animals. Even some 3-year-olds recognize this distinction (Gelman, 2003; Inagaki & Hatano, 2002).

Preschool children are able to deal with abstract concepts, as we discuss further in Chapter 2. The examples presented throughout the book illustrate the deep interrelationship between concepts and their related verbal descriptions. Consider the word *bat,* which refers to two very different concepts: *a nocturnal animal* and *a sports tool.* The different interpretations lead to very different inferences. For example, if someone tells you, "The bat is made of wood," you could infer that it is long, rigid, and used to hit balls. You would not infer that it eats, has babies, flies at night, and has good hearing.

PrePS incorporates lessons learned from extensive research on the acquisition of organized knowledge, which is fostered when learners are offered 1) multiple examples of the content and tools of a domain and 2) repeated opportunities to use the practices of the domain (Brown & Campione, 1996; Dunbar & Fugelsang, 2005; Gelman, 1998). PrePS also takes advantage of preschoolers' propensity to repeat a given task until they are satisfied with their own level of performance. Box 1.1 provides a particularly compelling example of this internal motivation.

Box 1.1

SPONTANEOUS SELF-CORRECTION

Annette Karmiloff-Smith and Barbel Inhelder (1974) designed a study in which preschool- and elementary-age children were given multiple opportunities to balance various blocks on top of a metal rod. Children assumed that all the blocks balanced at their geometric center but soon discovered that some blocks violated this rule. As the session progressed, the children adjusted their balancing strategies, moving from guesswork and random trial-and-error methods to purposeful attempts to determine which side of the block provided the best balance point. PrePS draws from a key finding: Children kept trying different solutions, even when this meant giving up a working strategy for one that did not work as well at first. Children went beyond simply making blocks balance to trying to figure out a rule for balancing. It is noteworthy that children were able to use the same blocks over and over again. However, if the authors had not weighted blocks in odd ways, it is unlikely that the children would have been motivated to search for a particular kind of rule (e.g., how to balance the blocks that looked alike but had different insides).

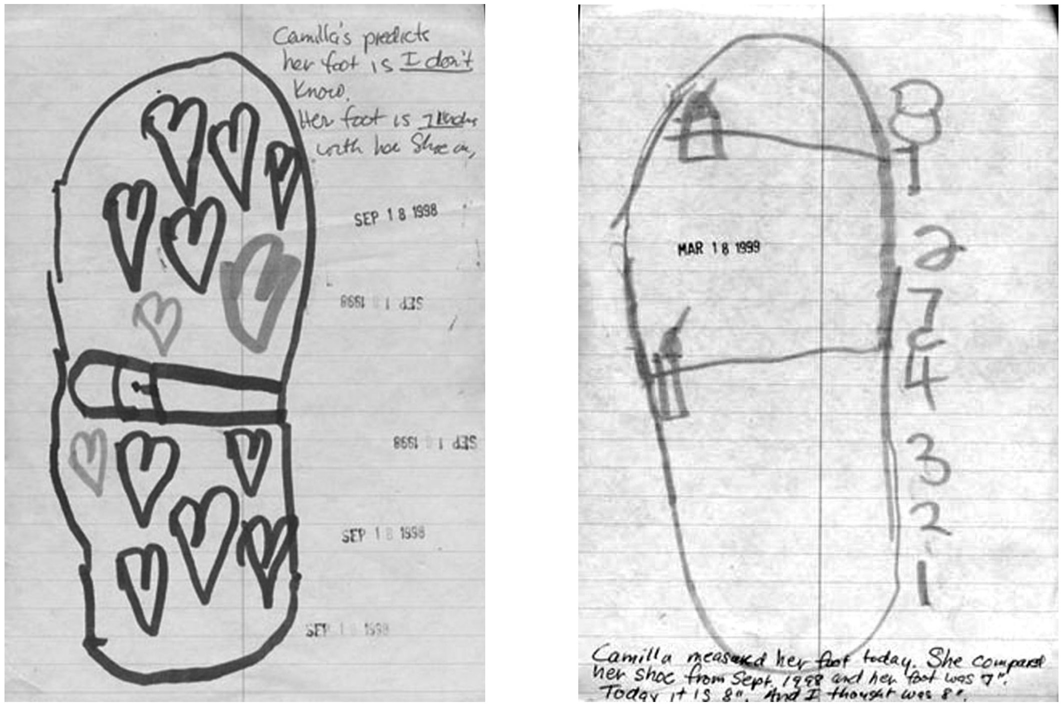
Many children have a habit of counting something over and over again, including steps, cracks in the sidewalk, or the number of telephone poles they pass while riding in the car. Children also are self-motivated to repeat a given activity. The extent to which these tendencies are engaged is critically related to the kinds of environments children encounter. If children are not offered a variety of environments that are about science, they are not likely to invent them. Even if they do invent such environments, there is no guarantee that children will know how to use and think about them. PrePS teachers serve a critical guiding role by providing children with repeated (ubiquitous), related (redundant) opportunities to work with a concept and to explore it scientifically. Redundancy and ubiquity foster organized learning.

Figure 1.1 provides an example of the principles of redundancy and ubiquity at work in the PrePS program. In September, a class of 4-year-old children traced one of their shoes. When the children were asked how large the shoe was, they had some difficulty answering. This same activity was repeated whenever each child got larger shoes so that throughout the year, children made multiple shoe entries in their science journals. They also learned to write numerals and to use a date stamp appropriately. These developments were due to the ubiquitous embedding of measuring and dating activities in various science-learning opportunities and clearly contributed to a shift in the quality of entries in the children's science journals. As seen in Figure 1.1A, at the start of the school year, one child decorated her shoe with hearts and stamped the date all over the page. When asked how large her shoe was, the child told her teacher that she did not know. Later in the year, before the child measured her new shoe, her teacher asked her to make a prediction. By this point in the school year, she was able to do so. Furthermore, after she measured her shoe, she spontaneously wrote the numerals along its right side (see Figure 1.1B). The child's spontaneous use of numbers is also noteworthy because she related them to measuring. By looking across journal entries, one can document progress in literacy and drawing skills. Journals become a noninvasive source of information about a child's progress during the school year.

Figure 1.1 illustrates another key feature of the PrePS program: ensuring that there are science tools in the everyday environment. Although preschoolers are self-motivated to question and discover, they often are unfamiliar with the physical tools (e.g., rulers, magnifying glasses, weights and scales, date stamps) and specific vocabulary of science (e.g., *observe, predict, research, record*). PrePS provides experiences that allow children to use these tools and words in simple but correct ways. As the year progresses, children start to understand how to use these tools and words independently because of multiple opportunities to use them with help from adults.

Although PrePS emphasizes the development of scientific thought, it encompasses many other social and cognitive skills: math and number abilities, early literacy and language skills, social communication, and emotional sensitivity. Mathematical skills are supported as children count, measure, and compare quantities while doing science. Likewise, literacy is enhanced as children record and date their observations and ask for books that can answer their questions. Science also requires children to think critically and to compare and contrast evidence from different sources.

Investigative activities help to develop abilities that go far beyond the scope of what one traditionally considers as science. PrePS strengthens basic decision-making and problem-solving skills, thus allowing children to seek and interpret information for themselves rather than to simply accept what authorities offer. Science requires



(a) (b)

Figure 1.1. Journal entry, before and after PrePS experience.

teamwork among individuals who encourage and respect the opinions of others. Sharing, respect for others and their ideas, and cooperation are necessary social skills for both scientists and preschoolers. This broader conception of science provides a lens through which to view and reevaluate typical preschool activities. Many opportunities for science activities already exist in preschool classrooms. For example, storytime can include nonfiction science books or stories with a science theme (see Chapter 3 for suggestions). If teachers include sharing time in the classroom schedule, they can guide children's sharing choices so that they relate to a topic under study. For example, as part of an investigation of the science concept of *change,* children can bring in "something that changes." Children's choices—which in our experiences have included a wide range of objects including a transforming toy, a flashlight, a change of clothes, and ice cubes—create an opportunity to discuss what change means and how much they already know about it. Box 1.2 illustrates how children and teachers can explore scientific ideas together during group time.

When science is understood as a process of studying the objects and events in the world by asking and answering questions, the scientific process can be integrated throughout the school day and included in a wide range of activities. Science is not a collection of unrelated activities that are inserted into particular time slots in a classroom schedule. One central tenet of the PrePS program is that experience and learning in one area leads to learning and understanding in conceptually related areas. For example, when learning about the human body, children may explore the form and function of different body parts (e.g., the shape and purpose of the teeth, joints, stomach, brain, legs, and heart). When children start thinking about the bod-

Box 1.2
DO INSECTS HAVE HEARTS?

As part of their exploration of insides and outsides, children were asked to think about what might be inside ants and cockroaches and to predict what was the same about them. One child suggested that both insects have hearts inside, but another child disagreed so the teacher asked the class to vote. Although all of his classmates agreed that ants and cockroaches have hearts, the lone dissenter stood his ground. This sparked a discussion about what kinds of things have hearts. One child reasoned that ants and cockroaches are living things and that all living things have hearts. Another child pointed out that plants are alive but do not have hearts. After hearing his classmates' ideas, the skeptical child suggested doing research to find a definitive answer.

The children in this classroom were learning science facts (e.g., ants and cockroaches are living things) and science vocabulary (e.g., *research*). They used critical thinking skills (e.g., plants are alive, yet they do not have hearts) to produce relevant information. This example also illustrates how PrePS encourages social and emotional development: One child possessed the self-confidence to express an opinion that differed from that of the class, and the other students respected his differing opinion.

ies of other kinds of animals, they will learn more effectively because they can build on what they already know and draw connections between one area of investigation (e.g., the shape and purpose of human body parts) and another (e.g., the shape and purpose of animal body parts). As children start to acquire new information and to apply knowledge across different areas, they feel pride in their sense of understanding and joy in making discoveries. They have the satisfaction of being active collaborators in their own education. These moments inspire children to learn more and to work together toward the goal of discovery.

As you read this book, you may be reminded of some or all of the following concepts:

1. Emergent curriculum, with the teacher as facilitator and not lecturer
2. Active, hands-on exploration
3. The integrated day
4. Webbing
5. The Reggio Emilia program (Wurm, 2005)
6. Montessori
7. Vygotsky and the zone of proximal development
8. Piaget's view of children as active learners who construct their understanding of the world

Indeed, we have been influenced by many aspects of other programs and theories, especially when these overlap with our ideas for doing and thinking about science. Many preschool teachers are already including some of the elements of PrePS in their classrooms by encouraging children to ask questions, solve problems, communicate, work and play in groups, and pay attention to details. These are thinking skills that can be applied to a variety of content domains, but their use and content will vary. For example, if children are having a pretend tea party, they need to select objects that are relevant to the script, such as a toy teapot, small cups, and tiny spoons. With science, the props should be items that encourage exploration and thinking about the nature of objects in the world.

In PrePS, science is not a rigid set of sophisticated experiments, formulas, and rules. Rather, *science* refers to an attitude—an intellectual approach to viewing the natural world—with an investigative method of asking and answering questions (and a willingness to entertain alternative explanations). Implementing PrePS requires changes in the conceptual approach to teaching, but it does not necessarily entail a comprehensive overhaul of the learning environment. As the teacher, you will be thinking and investigating (and encouraging the children to think and investigate) in ways that are increasingly structured, cooperative, and conceptually focused.

Chapter 2 reviews more topic areas about which preschool children know and, as Bowman et al. (2001) put it, are "eager to learn." It also describes the PrePS framework that can guide you and your students through conceptually connected learning experiences. Chapter 3 outlines how to use science practices with different content. Chapter 4 discusses the use of PrePS throughout the year, either as a primary or complementary program. Finally, Chapter 5 delves into issues of assessment.

CONCLUSION

Some key ideas permeate this book. First, in learning science, knowledge about the world is related to the practices and tools of science. Together, the conceptual–language side and the practice–tool side form a coherent approach to how science is characterized and carried out.

In teaching the conceptual–language aspect of science, the following items should be considered:

1. Concepts do not stand alone; they are organized in a coherent way and support inferences.

2. Understanding of vocabulary is related to understanding of related concepts. In a sense, concepts and their related terms are opposite sides of the same coin.

3. If one already has some knowledge about a concept, further learning about that concept is facilitated.

4. Young children use what they know to participate actively in their own learning.

5. Young children have organized knowledge about some core domains (see Chapter 2).

6. Providing multiple and related examples to young children gives them the opportunity to engage actively in concept and language learning. Withholding such opportunities is akin to producing a deprivation environment.

7. Redundant and ubiquitous opportunities to work with a concept and its language are critical conditions for conceptual development, but this takes time and planning on the part of the teacher.

8. Planning activities and learning experiences that are connected to one another helps children find these connections.

When teaching science practices, the following items should be considered:

1. Careful observations are needed to gain information.

2. Predicting and checking are fundamental science practices.

3. Comparing and contrasting are also fundamental practices; they can lead to the idea of a variable.

4. Data should be recorded by drawing, writing, and using numerals to represent them.

5. Work should be dated.

6. Scientific vocabulary should be used in context.

7. The environment should be filled with tools (e.g., rulers and measuring devices, magnifiers). Guidance about using tools, along with opportunities to do so, should be provided.

8. Opportunities for children to communicate about their findings should be provided.

9. Take time with new concepts, ideas, and skills. Be patient as you encourage children to practice, explore, and build understanding.