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"We Learn How to Predict and be a Scientist": Early Science Experiences and Kindergarten Children's Social Meanings About Science

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We examine kindergarten children's emerging social meanings about science as a function of their participation in integrated science inquiry and literacy activities associated with the Scientific Literacy Project (SLP). We describe changes in 123 SLP kindergarten children's narrative accounts of learning science in school during three different time periods: (a) in September, before the onset of SLP activities; (b) in December, after children had participated in 17 lessons associated with 4 SLP units; and (c) in March, after children had participated in an additional 13 lessons associated with the SLP Marine Life unit. At the end of the year, we: (a) compare SLP children's narratives about science to those of a group of children ($n = 70$) who only experienced the regular kindergarten program; and (b) examine differences between SLP and comparison children's reports on a measure of learning activities in kindergarten that include science as well as privileged content areas such as reading, writing, and learning about numbers and shapes. Results support the conclusion that sustained and meaningful participation in conceptually coherent science programs is crucial for children to develop meanings about science as a distinct academic domain that comprises its own disciplinary content, language, and processes.

Scientific literacy for all Americans has been highlighted as a target goal for science education, beginning in the early school years and continuing into adulthood (American Association for the Advancement of Science, 2008; National Research Council, 2000, 2001, 2007). Although a plurality of positions have been articulated about what constitutes scientific literacy, there is growing recognition that context plays a vital role in shaping individuals' conceptions about science, regardless of expertise or developmental level (Hogan, 2000; Roberts, 2007; Samarapungavan, Westby, & Bodner, 2006; Sandoval, 2005). Ideas about science as a discipline with its own norms, language, content, and processes are socially constructed. They emerge through praxis, as individuals engage in shared, culturally meaningful activities (Kelly, Chen, & Crawford, 1998; Layton, 1991; Roth & Lee, 2007). Therefore, the salience and types of science activities that children experience—at school, within families, during extracurricular activities,

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and through the media—have implications for the way they construct ideas about what counts as science.

At the beginning of school, young children are afforded few opportunities for learning science. On average, less than 10% of instructional time is spent on teaching science in the early grades (National Center for Education Statistics, 1997; National Institute of Child Health and Human Development, 2005; Weiss, Pasley, Smith, Banilower, & Heck, 2003). Science instruction occurs sporadically, and rarely engages children in practices that encourage rigorous and reflective science learning (Fulp, 2002).

This state of affairs is a barrier to the development of understandings about science and may account for children's stereotypical views of science as a male-oriented, laboratory-based activity (Barman, 1999; Buldu, 2006; Finson, 2002). Inadequate attention to science in the early grades may signal to children that science is less important and therefore less valued than other academic subjects such as reading or math. To remove this barrier, science reform recommendations emphasize the need for inquiry-based instructional practices that promote early, meaningful, and sustained engagement with science (e.g., Anderson & Helms, 2001; National Research Council, 2000, 2001, 2007; Rennie, Feher, Dierking, & Falk, 2003).

In this study, we focus on kindergarten children's emerging social meanings about science and examine whether they vary with engagement in literacy-rich, inquiry science activities. We collected data at three points during the school year from a group of ethnically diverse, public school kindergarteners who participated in the Scientific Literacy Project (SLP)—a science program of integrated inquiry and literacy activities for young children (Mantzicopoulos, Patrick, & Samarapungavan, 2005). In addition to examining changes in the SLP sample over the course of the year, we investigated end-of-year differences between SLP children and a comparable group of children who participated in the regular kindergarten program that did not include the added SLP activities.

THEORETICAL FRAMEWORK

Young Children and Inquiry Science

Over a decade ago, powerful arguments were made about the need for science programs that provide young children with opportunities for authentic, goal-focused science inquiry experiences (Brown, Campione, Metz, & Ash, 1997; Metz, 1995, 1997). At the same time, concerns were expressed about the consequences of developmental readiness perspectives on children's science learning. Within readiness-focused approaches, young children are viewed as relatively unskilled, concrete thinkers. Purposeful science inquiry is thus postponed until later in school, after children have mastered discrete sets of "science" tasks (e.g., categorizing, observing, classifying). Yet, promoting science as a set of decontextualized, fragmented skills and knowledge is likely to undermine not only the development of children's interest but also their understanding about and valuing of science as a discipline. Moreover, a readiness approach to science learning overlooks the role of instruction as a means for facilitating a cohesive framework "wherein the processes previously approached in the elementary school grades as ends in themselves become tools in a more contextualized authentic scientific inquiry" (Metz, 1995, p. 1). Evidence based on research with children in second grade and a combined fourth/fifth-grade class is consistent with this claim.

The knowledge children gain as they participate in scientific investigations also contributes to their increasing understanding of the nature of science (i.e., science as a way of knowing about the world) (Metz, 2004).

Recently, results from groups of first, second, and third graders who participated in *Integrated Science Literacy Enactments* (ISLE), a program of integrated inquiry and literacy activities (Varelas & Pappas, 2006; Varelas, Pappas, Kane, Arsenault, Hankes, & Cowan, 2008), confirm that within inquiry-based, literacy-rich environments, children appropriate the language of science as they think and communicate about science. Although grade-level comparisons were not made, analysis of episodes involving classroom discourse among the children, as well as between the children and their teachers, demonstrates that affording opportunities for children to use argumentation bridges their everyday experiences with the "ways of science."

In addition to programs for children in the early grades of elementary school, there is emerging evidence, based on data collected as part of the Scientific Literacy Project, that even younger children can profit from inquiry-oriented science. Early findings, suggesting that kindergarteners develop a functional understanding of scientific inquiry, are reported for children who participated in a 5-week SLP inquiry unit about the life cycle of the butterfly (Samarapungavan, Mantzicopoulos, & Patrick, 2008). Multiple sources of data (e.g., artifacts such as science notebook entries, photographs, activity boards, as well as video-recordings of children engaged in science activities) substantiated that children asked meaningful questions, made predictions about outcomes, observed and recorded evidence, revised and represented their knowledge, and communicated their findings.

Conclusions that may be drawn from current research programs include that it is both realistic and feasible to implement early education programs that encourage participation in contextually rich inquiry experiences, as opposed to engagement with discrete sets of process tasks (e.g., sorting objects). Information collected as children enact science in the classroom (e.g., analysis of the moment-to-moment classroom discourse, artifacts developed in the course of the inquiry activities), as well as from assessments designed to document science learning, confirms that participation in inquiry science promotes children's science learning.

Young Children's Social Meanings About the Practice of Science

Situated Perspectives. A common thread among the two recent approaches to science programs for young children presented here (i.e., ISLE, SLP) is the view of science learning as socially negotiated and constructed within specific classroom contexts. Consistent with socioculturally centered approaches (e.g., Kelly et al., 1998), discourse plays a central role in how children develop social meanings from their everyday experiences. What "counts as science is accomplished interactionally among members through discourse processes within a particular community" (p. 26). It is through language that members of the classroom negotiate social roles, norms, expectations, and reconstruct complex, new meanings (Lemke, 1990).

Within sociocultural perspectives, the study of social practices in the classroom is privileged because meaning exists in the collective: It belongs to the members of the classroom rather than to an individual (Kelly & Crawford, 1997). However, meaning making also occurs at the individual level as children reconstruct and appropriate the social discourses of their cultures, including school (Hicks, 1996).

In her framework for a discourse-oriented methodology, Hicks (1996) addresses both the individual and the collective by positing four important themes as methodological guides for children's "discursive activity" (p. 113). Applied to science-oriented classroom settings these involve: (a) the shared contexts of meaning that constitute science-related social activity; (b) the construction of what it means to do science and how it is enacted within particular activities in the classroom; (c) individual children's contributions to the flow of science-related activity; and (d) children's reconstruction of the social meaning of science over time.

We have begun to address the first three questions in prior work (e.g., Samarapungavan et al., 2008). In the present study, we consider the fourth question and ask: How do children re-construct and appropriate the science-related discourses of their classroom outside of the immediate classroom context? What are their emerging understandings about what events, activities, processes, or knowledge count as science? And, to what extent do these understandings reflect children's classroom or other experiences with science?

We use an interview methodology and suggest that as children share with us their socially derived meanings of what counts as science, they do not simply share replicas of an objective reality of science-related experiences. Rather, children's meaning making about what counts as science is situated in their social worlds and represents patterns of ideas that they "assemble on the spot" as they communicate about past experiences (Gee, 2005). In the process of reflecting and talking about what counts as science, the child enters into a "dialogic response" with the science-related discourses of his/her classroom or other settings (Hicks, 1996). What emerges is a new discourse that simultaneously responds to and integrates the knowledge and shared cultural practices of the contexts that involve science.

Our approach, though it may shed light on children's emergent epistemic notions, is not a study of epistemological beliefs in relationship to specific inquiry practices in the classroom (e.g., Metz, 2004), or to science scenarios presented during an interview (e.g., Linn & Songer, 1993), or to broad questions about the goals of science (e.g., Smith, Maclin, Houghton, & Hennessey, 2000). We do, however, recognize that children's re-constructions during the interview may also provide insights into their emergent understandings about the nature of science. Therefore, in light of the plurality of positions and approaches to older students' knowledge about the nature of science, recent distinctions about situated versus decontextualized notions of epistemological beliefs have some relevance for our work. Hogan (2000), for instance, differentiates between distal (knowledge about the professional practice of science in the scientific community) and proximal knowledge that refers to "students' frameworks about science in their own contexts of learning" (p. 56). These concern both students' beliefs about the nature of science as well as knowledge about themselves as science learners. In related work, Sandoval (2005) has proposed a distinction between formal epistemologies (a term synonymous with Hogan's distal knowledge), and practical epistemologies (beliefs about students' own knowledge and practice in school science). As young children construct social meanings about science, they may draw on proximal knowledge that comes from their classroom-related science experiences. However, children may hold different values about the relevance of science for them and may have varying beliefs about what counts as science, depending on how they negotiate their participation within an array of contextual affordances (e.g., family conversations about science, media influences, or formal science instruction at school). All these result from social processes of children in practice and represent children's lived experiences.

Thus, our perspective is compatible, although not directly aligned, with research on ISLE children's social knowledge about science (Tucker-Raymond, Varelas, Pappas, Korzh, & Wentland, 2007). Using a narrative identity lens to study children's uptake of science practices and activities, Tucker-Raymond et al. argued that children's scientist identities emerge from knowledge involving a range of "lived" experiences in and out of school. Children's drawings of themselves in science, as well as narratives obtained in individual interviews with 36 students in grades 1 through 3 over a 10-week sequence, reflected children's "choices, ideologies and commitments as a part of the social activity systems with particular tools and signs" (p. 566). In-depth interviews with three students (in grades 2–3) highlighted changes in children's views before and after participation in ISLE. These confirmed a move from descriptions of science as an enterprise of making things to views of science that were emphasized in the program (i.e., science as an investigative process that involves asking questions, making predictions, conducting experiments, and sharing findings).

In the present study, rather than focusing on children's emergent identities, we gave primacy to children's constructions (re-constructions) of their science-related social worlds. We do recognize, nevertheless, that both psychological (e.g., Fivush & Haden, 2003; McAdams, Josselson, & Lieblich, 2006; Winston et al., 2004) and sociocultural (e.g., Brown, Reveles, & Kelly, 2005; Gee, 2005) perspectives view identity as embedded in discursive activity. Thus, through their narratives children also communicate conceptions of themselves situated in discourse contexts involving science.

Contributions from Theoretically and Content-Distinct Studies. An important issue for research based on young children's interview narratives involves developmental limitations in children's verbal expression skills and limited information processing abilities (Beitchman & Corradini, 1988; Martin, 1986). Nevertheless, children know more than they may actually express (Foster, 1990) and, when probed specifically about typical and familiar experiences, even very young children can provide a wealth of psychological information about themselves and others (Eder, 1989). However, we did not find studies that used interview techniques to engage very young children in discussions about science. Considering that the interview process is a discourse-oriented tool that simultaneously engages children in the recall and reconstruction of personally meaningful contexts and social discourses, we took into account findings from early memory as well as early literacy research.

Using semi-structured interview methodologies, memory researchers have shown that, as early as three years of age, children provide meaningful and coherent representations of their experiences (Hudson, Fivush, & Kuebli, 1992). This work was directed at understanding the structure and development of early memory (e.g., Fivush, Kuebli, & Clubb, 1992; Piolino et al., 2007) rather than children's social interpretations of their lived experiences. However, despite being theoretically and empirically distinct from our approach, it confirms that preschoolers have the capacity to represent aspects of personally experienced events (e.g., their school day, visits to the museum, zoo, amusement park, or to see a pirate) (DeMarie, Norman, & Abshier, 2000; Fivush, 1984; Hamond & Fivush, 1991; Murachver, Pipe, Gordon, Owens, & Fivush, 1996). Both experimental (e.g., Murachver et al., 1996) and field studies (e.g., DeMarie et al., 2000; Tessler & Nelson, 1994) have addressed the role of the social context and language in children's learning about an event. Interview narratives were more complete, more coherent, and better organized when events were not simply observed by the children, but included opportunities for shared participation and discussion (Haden, 2003). This body of research further suggests that narrative activity has important implications for self-awareness and identity formation. As children re-construct their experiences through narrative they also build a sense of identity and self-understanding (Fivush & Haden, 2003).

In research about preschool and kindergarten children's social meanings about school in general, and literacy in particular, it is also shown that children's conceptions reflect the activities, procedures, routines, values, and attitudes characteristic of the social and instructional contexts of specific settings (Wiltz & Klein, 2001). Children's constructions of daily school routines (e.g., story time, circle time, nap, gym, going home) show parallels to teachers' daily plans (Reifel, 1988). Moreover, when asked about routine academic events such as literacy instruction, children's discourse reflects the language and component activities (e.g., writing, stamping, using envelopes) characteristic of the social environments in which these activities were embedded (Wiltz & Klein, 2001). Consistent with findings from early memory studies, children's reflections about their learning and social experiences became richer and more detailed with increasing experience in each particular setting.

Not surprisingly, studies confirm substantial differences between children's social meanings across different instructional contexts. Children's accounts of various aspects of literacy instruction (e.g., writing words, drawing pictures, writing stories, sharing one's writing) corresponded to the types of learning experiences and the discourse activity in each classroom (Nolen, 2001; Wiltz & Klein, 2001). Features of the instructional context such as the types and variety of literacy tasks, as well as the amount of time allocated to activities, communicate to children how much those tasks are valued and are essential to the meanings that children constructed about literacy (Nolen, 2001; Turner, 1995). On the basis of this evidence we expect that children's narratives about science will highlight aspects of their familiar worlds within which their involvement with science was grounded.

Pilot Work on Children's Social Meanings About Science. In our own pilot work we examined kindergarten children's interview narratives to gain insights into how they integrate and appropriate social meanings about what counts as science (Mantzicopoulos, Patrick, & Samarapungavan, 2008). Early interviews with 48 kindergarteners who participated in the SLP suggest that children construct meaningful and highly situated responses to questions about "what is science?" and "what happens in science?" Consistent with Tucker-Raymond et al. (2007), at the end of a 10-week program of SLP inquiry and literacy activities on living things and marine life, children's narrative meanings re-constructed their instructional experiences with science (Mantzicopoulos, et al., 2008). However, our study (a) did not access children's social constructions of science prior to participation in the SLP; and (b) did not include children from regular kindergarten classrooms that did not implement the SLP activities. We address these issues in this article.

THE CURRENT STUDY

In the present study, we expand our analytic scheme and examine children's social meanings about science over time and as a function of participation in five units of integrated science inquiry and literacy activities in the fall and spring of kindergarten. First, we ask whether children come to school with already structured meanings about science. We expect that few children will begin school with coherent sets of ideas about what science involves, simply because science is an overarching term for many diverse disciplines. Parents may not use the term even when they engage in science activities with their children. Also, children, including those with preschool experience, may have had little exposure to science. At the beginning of school the curriculum is dominated by a focus on language arts (Duke, 2000; Lanahan, Princiotta, & Enyeart, 2006), and parents of young children are given strong messages about the key role of reading for children's school success. Comparable messages about the role of science are not typical.

Second, we examine children's narratives about science over time as a function of participation in the SLP. We reason that, much like research with other academic subjects (e.g., reading), children's emergent social understanding of science, over time, should reflect their increasing experience with the content and processes of science as enacted in the context of the SLP activities.

Third, we investigate differences between children who participated in the SLP activities and children who did not. We expect that at the end of the school year, SLP children's narratives should differ from the narratives of comparison peers who experienced only the regular kindergarten curriculum, without the SLP activities. We hypothesize that children, both in SLP and comparison schools, will ascribe meanings to science consistent with their experiences in their respective school contexts. If science instruction in the comparison classrooms represents the instructional trends for science referenced earlier in this article, it is not clear how it will shape students' views about science. Research on children's social meanings of literacy suggests that "students' definitions of reading and writing are shaped, in part, by the choice of frequent literacy activities" (Nolen, 2001, p. 111). Without explicit instruction, students' meanings may include images of science as reflected in television shows, or as enacted through family activities and conversations. On the other hand, the literature supports the argument that children's interpretations of science as a discipline with its own academic content, processes, and language evolve with participation in programs that, like the SLP: (a) are thematically and conceptually coherent; (b) include explicit focus on science as a process; and (c) provide opportunities for cognitively guided learning and discourse about science.

SUMMARY OF RESEARCH OBJECTIVES

We describe changes in SLP kindergarten children's narrative accounts about science during three different time periods: (a) in September, before the onset of the SLP activities; (b) in December, after children had participated in four SLP units; and (c) in March, after children had participated in a total of five SLP units. At the end of the year we: (a) compare SLP children's narratives about science to those of a group of children who experienced only the regular kindergarten program and (b) examine differences between SLP and comparison children's reports to items assessing a range of learning activities in kindergarten that include science as well as privileged content areas such are reading, writing, and learning about numbers and shapes.

METHOD

Participants

The sample comprised 193 kindergarten children in 4 different schools located in a midwestern suburban school district. Children in Schools 1 and 2 (SLP group; $n = 123$) participated in science activities associated with the SLP. Children in schools 3 and 4 were recruited in the spring of the school year and served as the comparison sample (COMP Group; $n = 70$). Comparison (COMP) schools were geographically close to the SLP schools. They were selected after reviewing each school's demographic and achievement characteristics, provided by the state's Department of Education. Both COMP and SLP schools served relatively high numbers of students living in poverty and performing below the state average on the state's academic achievement test. Specifically, the proportion of students passing both the reading and math state achievement test in third grade was 51% (school 1), 54% (school 2), 52% (school 3), and 63% (school 4). The average percentage of students receiving free and reduced-cost lunch across the four schools was 61.2%.

In the SLP schools we worked with five kindergarten teachers in six different classrooms. The teachers' years of teaching experience ranged from 1 to 23 years. One of the teachers had a student teacher in the final semester of her student-teaching experience, and she also participated in the last two SLP units. We obtained informed consent from 167 children (i.e., 96% of the children who were enrolled in kindergarten) but at the end of the year had complete data across the three data collection periods from 123 children. Of the 44 children excluded because of incomplete data, 16 left at or before the mid-year assessments, 6 were assigned to special education and/or had severe language difficulties, and 22 had only end-of-year data because they enrolled at the school after the mid-year assessments.

Throughout the duration of the SLP activities we tracked children's attendance. Our data show that 113 of the children (92%) were in attendance for more than 70% of the time, whereas only 10 children had low attendance (ranging from 44% to 68%) either due to illness or family circumstances (e.g., moves). These attendance data parallel those reported by the state for the study schools. To preserve the ecological validity of the study, we included all children in the analyses because their attendance patterns were representative of the children's school experience.

In the COMP schools, 3 teachers (4 classrooms) and 68 children with informed consent (80.3% of the total students in these classrooms) were recruited for this study. In addition, two children who had initially enrolled at SLP schools and who transferred to one of the COMP schools in the fall were part of this sample ($n = 70$). In the COMP schools, the teachers' years of experience ranged from 1 to 6 years.

We conducted a series of χ^2 tests to compare the SLP and COMP children on sex, ethnicity, and free lunch status; there were no statistically significant differences. There were 99 boys and 94 girls. The ethnic distribution of the sample, according to school records, was as follows: 102 children were Caucasian; 13 were African American; 48 were Hispanic; 25 were Multiracial; and 5 were Other. Free lunch data were collected from school records and were available for 187 children; 132 children (70.6%) received free or reduced-cost lunch. This percentage of kindergarteners receiving free or reduced-cost lunch is higher than the percentage reported for all the students in the four schools (61.2%).

Context of Science Activities in the SLP and Comparison Classrooms

In this section we provide an overview of the SLP and COMP instructional contexts. For the SLP group, we use information from the SLP teacher guides (Samarapungavan, 2008), the classroom videotapes, comments made during teacher interviews, and descriptive data from the fidelity rubrics for the inquiry and literacy activities. For the COMP classrooms we use information from teacher interviews and videotaped observations to describe the science instructional contexts and lessons. We thus document that SLP students participated in science instructional experiences, beyond those provided in regular classrooms.

Overview of SLP. The SLP emphasizes cognitively guided learning and is based on tenets of sociocultural theories. It is aligned with perspectives that situate teaching and learning within meaningful instructional contexts for the developing child (e.g., Rogoff, 1990; Tharp & Gallimore, 1988), and that underscore the need for continuity of experience. Thus, SLP incorporates principles recognized as fundamental for teaching and learning (e.g., Brown, 1997; Bruner, 1996; Wells, 1999) including: (a) agency (i.e., developing control over one's own mental activity); (b) inquiry and reflection (i.e., making sense of what is learned); (c) collaboration between the participants in teaching and learning; (d) a culture that supports and values the importance of guided inquiry-based learning; (e) grounding early science instruction in disciplinary content; and (f) using knowledge about children's development and learning to guide instructional choices.

Conceptual Framework and Rationale. The SLP science activities are designed to capture features of science as a set of cultural practices for young children. Many scholars in the history and philosophy of science have emphasized the sociocultural dimensions of doing science, describing science as a set of sociocultural practices that allow for the construction and evaluation of scientific knowledge based on shared epistemic and methodological norms and values (Giere, 1988; Knorr-Cetina, 1999; Kuhn, 1962, 1977; Laudan, 1990). Thus, the SLP is an attempt to initiate very young novices into the culture of science using guided inquiry pedagogy (Brown & Campione, 1994; Magnusson & Palincsar, 1995).

The SLP activities are consistent with the National Research Council's recommendations for science (2000, 2001, 2007). These underscore the instructional importance of integrated inquiry and literacy activities to address scientifically rich and developmentally appropriate questions that relate to students' interests and experiences. We focus on integrated instruction that acknowledges disciplinary integrity (Dickinson & Young, 1998; Huntley, 1998; Stoddart, Pinal, Latzke, & Canaday, 2002) so that SLP activities provide a context for disciplines to interact and support each other, while each maintains its disciplinary context and boundaries.

The content of the inquiry and literacy activities was created jointly by the SLP researchers and the collaborating teachers. The teachers identified topics that they had taught in previous years or were interested in teaching, and the SLP team worked closely with teachers to develop and refine the activities that the teachers could infuse into their science teaching. Our goal was to encourage teachers to: (a) spend more time on fewer, carefully selected themes (e.g., biological structure and function, biological adaptation, and biological growth and development), rather than touch briefly on a number of stand-alone science topics and discrete activities, as they reported they had done in the past and (b) revisit these themes throughout the year. To provide young children with multiple opportunities to learn about the content, processes, and language of science, we worked with the teachers on the following three dimensions of science teaching and learning: (a) strengthening the conceptual coherence of the science curriculum; (b) enhancing the use of science inquiry activities; and (c) integrating science literacy activities with the inquiry components of SLP.

We developed six thematic units in collaboration with participating classroom teachers. The data for this investigation, however, were collected at the end of the first five units, which are outlined in Table 1. The key science concepts targeted in these SLP units are shown in Table 2. Key themes or ideas about the nature and processes of scientific inquiry, biological structure, function, adaption, and motion were integrated into several units across the year. The intervention was designed to provide children with opportunities to construct, develop, and revisit key ideas during the course of the program.

Throughout the development of the SLP activities, we were aware that the scientifically normative counterparts of the ideas that the children consider in the SLP curriculum are beyond the reach of typically developing kindergarteners. We thus reasoned that five-year-olds begin kindergarten as a kind of universal novice, lacking both systematic content knowledge as well as important cognitive tools of literacy and numeracy. Therefore, we do not claim that participation in the SLP intervention would provide children with normatively accurate scientific concepts for the topics addressed. Rather, the goal of SLP instruction was to find entry points in phenomenological experiences for children to think and talk about the natural world around them. An additional goal was for SLP teachers to scaffold children's understanding of the role of thought, inference, and prior experience in organizing scientific practice as they began to construct approximations of scientific concepts and develop a language for thinking about science.

Most of the SLP activities focused on biological concepts, for three reasons. First, the teachers expressed a strong interest in biology themes and noted that these were already included in their kindergarten curriculum. Second, developmental research has shown that young children have developed biological concepts before the onset of formal schooling and use their biological concepts to predict biological phenomena, make causal inferences, and categorize natural kinds (Ahn et al., 2001; Greif, Kemler Nelson, Keil, & Guitierrez, 2006; Inagaki & Hatano, 2004). Third, children's experiences with plants and animals in their environment make biological phenomena accessible.

The general focus of the project was on children's understanding of living things and their characteristics. Over the course of the activities, children learned about the properties of living things, how to distinguish living things from non-living things (e.g., living things have self-initiated motion while non-living things move only under the influence of external forces), and how living things adapt to their environments or habitats. In addition, we included a unit on force and motion because: (a) it provided children with an opportunity to discuss differences in movement between living and non-living things and (b) the teachers specifically requested it, given that motion was listed in the state science standards for kindergarten, and they were not confident about how to address it. Our goal here was not to teach children about scientific notions of force or speed, but to engage them in simple experiments (e.g., investigations to determine how factors such as the slope of ramps and the relative roughness of ramp surfaces influenced how fast objects moved down the ramp).

TABLE 1
Outline of SLP Inquiry and Literacy Activities Covered in the SLP Units

Unit	*n of Lessons*	*Description*	*Readings*
What is Science?	3	This unit is the first of the SLP units. It introduces children to the key themes of the SLP curriculum which are that science is the study of the natural world, and that children can do science through planned and purposeful investigations in which they examine and revise their conjectures or models of the world by gathering and interpreting empirical data. Teachers introduce children to scientific inquiry through simple experiments with dissolving (for example, examining what happens to a variety of objects such lemonade mix, salt, beans, and a metal paper clip, in water). The teachers scaffold discussions about what it means to do science.	Yu, N. (2006). *Science is everywhere*. Waterbury, CT: Abrams. Pitino, D. M. (2007). *Amazing scientists*. Waterbury, CT: Abrams.
Living Things	8	In this unit the children investigate the properties of living things. The inquiry unit is based on observations of animals and plants in the children's environment. The unit is designed to help children explore important topics in biology such as: (a) differences between living and non living things; (b) habitats and how living things are adapted to their habitats; (c) structure and function, or how animal bodies enable them to function and survive. Children learn about these concepts by going on nature walks to observe living and non-living things in their environments, recording observations in their science notebooks with digital photographs, drawings, and writing (using invented spelling or by dictating to an adult).	Trussell-Cullen, A. (2001). *Living things*. Carlsbad, CA: Dominie Press. Street, S. (2001). *Living things need water*. National Geographic. Santiago, R. O. (2006). *Amazing plants*. Waterbury, CT: Abrams. Wong, G. (1996). *Plants and animals live here*. National Geographic. Mantzicopoulos, P. Y. (2006). *Whose eye is it*? The Scientific Literacy Project.
Tools	2	This unit is designed to introduce ideas of scientific recording and measurement. Children learn about several tools for observing and measuring (e.g., a ruler, magnifying glass, balance scales) and use these during their own investigations throughout the SLP activities. For example, teachers introduce children to simple measurement of length with a ruler using inches as a unit of measurement. The teachers facilitate a discussion of using a uniform starting point and uniform units for measuring length. Teachers also introduce the use of balance scales as a tool to determine which of two objects is heavier. The goal of this unit was not teach formal mathematical concepts of measurement but to give children simple functional tools for observing and recording things such as relative size.	Mulcahy, M. (2006). *How scientists observe*. Waterbury, CT: Abrams. Casteel, C. N. (2006). *Let's measure with tools*. Waterbury, CT: Abrams.

Force & Motion	4	In this unit the children investigate how things move. The inquiry unit is based on observations of various types of motion. Children discuss differences in movement between living and non living things and conduct simple experiments to determine how factors such as the slope of ramps, and the relative roughness of ramp surfaces influence how fast objects move down the ramp.	Ramirez, M. (2007). *Force and motion*. Waterbury, CT: Abrams. Pitino, D. M. (2006). *Playground science*. Waterbury, CT: Abrams.
Marine Life	13	In this unit the children investigate marine life and the properties of living things. The inquiry unit is based on observations of animals in a saltwater aquarium. The unit is designed to help children explore important topics in biology such as the differences between living and non living things, habitats and how living things are adapted to their habitats, structure and function, or how animal bodies enable them to function and survive.	Smith, J. (2005). *Living things are everywhere*. Abrams. Swartz, S. L. (2002). *Fish*. Parsippany, NJ: Dominie Press. Douglas, L. G. (2005). *Kelp*. NY: Scholastic. Hughes, M. (2005). *What is an ocean*? Chicago, IL: Heinemann Library. Zoehfeld, K. W. (1994). *What lives in a shell*? NY: HarperCollins Children's Books. Swartz, S. L. (2002). *Fish that hide*. Parsippany, NJ: Dominie Press. Pfeffer, W. (1996). *What's it like to be a fish*? NY: HarperCollins Children's Books.

TABLE 2
Key Science Concepts Targeted in the SLP Units

Science Concepts and Subcomponents	*Units*
Scientific Inquiry Processes • Understand that science as a process of inquiry is based on asking questions and making predictions about the natural world. • Understand the empirical basis of science: Scientific ideas are evaluated by their fit to empirical evidence. • Understand technological aspects of science as a set of cultural practices, such as the use of tools for gathering, recording, analyzing, and sharing data.	 • What is Science? • Living Things • Tools • Force and Motion • Marine Life
Life Science • Understand the characteristics of living things. For example, that they: need air, water, and food, respond to their environment, reproduce. • Structure and Function: Understand that plants and animals have specific structures and traits (e.g., physical and behavioral characteristics) that help them survive, grow, and reproduce. • Understand that living things have life cycles: They are born, develop into adults, reproduce, and eventually die.	 • What is Science? • Living Things • Marine Life
Physical Science • Describe objects in terms of the material they are made of. • Describe various ways in which things move and how factors such as friction influence motion.	 • What is Science? • Living Things • Tools • Force and Motion

In the next sections, we describe the inquiry and literacy activities and include examples of interactions between children and teachers. We then outline the procedures used for teacher training and support during the implementation of the activities, and present summary data from the inquiry and reading fidelity rubrics.

In the episodes included here, the children's and teachers' names are pseudonyms and, as an additional safeguard, we refer to all teachers as Ms. The transcripts represent typical, rather than exemplary, instances of instructional exchanges during the course of the inquiry and reading activities. As we note in the upcoming section on the implementation of the SLP activities, we collaborated with teachers who, despite being keen about incorporating science in their curriculum, were not familiar with inquiry-based teaching. During the course of our work with the teachers, it became clear that they acknowledged the need for shifts in their (a) established repertoires of teacher-centered, primarily large group instruction and (b) beliefs about young children's limited capacity for engaging in science discourse as well as for asking meaningful questions, reflecting on, and explaining their ideas. However, making these changes was challenging for the teachers. For example, teachers found it difficult to negotiate the need to scaffold student learning and to manage the flow of discourse as students generated ideas, and this at times threatened their own sense of efficacy for teaching science. Also, there were times when teachers reverted to using their familiar styles of expository teaching in lieu of exploration of student ideas through discussion. It must be noted, however, that these teachers were still new to SLP; three had piloted activities in the previous year for five weeks, and one teacher had spent ten weeks piloting activities. Similar challenges for teachers have been reported when inquiry-based science has been implemented with older children (e.g., Anderson, 2007; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Marx, Blumenfeld, Krajcik, & Soloway, 1997).

Inquiry Activities. One consideration in designing the inquiry activities was to find phenomenological contexts and experiences that allowed children to create meaningful new knowledge. Because of the young age of the children we did not expect them to form fully developed and normatively accurate scientific concepts from their inquiry activities. Rather, we expected students to develop reasonable approximations or precursors of formal scientific concepts as well as a sense of what it means to do science. To ensure that children could productively engage in inquiry, we had to select topics that children could investigate with the cognitive resources that were available to them or that could be developed through instructional support. Some forms of instructional support (e.g., the choice of topic, the observational environment, and the use of certain tools and artifacts in the conduct of the investigations) were built into the instructional design by the SLP research team in collaboration with the classroom teachers. The classroom teachers were also trained to provide contextual forms of support for children's inquiry, such as modeling aspects of inquiry, scaffolding children's knowledge construction, and scaffolding their science discourse through hints, questions, and requests for clarification (see Samarapungavan et al., 2008 for examples).

The goal of the SLP is to enhance children's functional understanding of inquiry as manifest in their ability to engage in scientific investigations that help them articulate and revise their models of the world. For example, in examining children's understanding of scientific inquiry we were interested in developing children's ability to make and evaluate scientifically meaningful predictions through the course of their own investigations and to identify instances of predictions in concrete scenarios. Classroom discussions representing these instances include: (a) episodes from Ms. Tarkington's class (see second episode under pre-inquiry activities and the episode associated with the literacy activities); and (b) an episode from Ms. Barr's class (inquiry activities).

The empirical framework for the children's investigations was primarily that of (semi) naturalistic observation. For example, the children went on nature walks to identify and categorize samples of living and non-living things, and they observed the behavior of marine life in a saltwater aquarium. Although the framework for the investigations was provided by the teacher, the design afforded children opportunities to decide what they wanted to explore, what to observe and record, and to draw conclusions from their investigations. Developmental research indicates that whereas young children may not possess the cognitive resources of adults or scientists when it comes to designing controlled experiments and evaluating the fit of models to data (Klahr, 2000; Kuhn & Dean, 2004; Masnick & Klahr, 2003; Schauble, 1996) they can revise their concepts in the face of significant new evidence (Carey, 2004; Carey & Sarnecka, 2006; Gopnik et al., 2004; Metz, 2004).

Within each unit, activities were grouped into three broad phases: pre-inquiry, inquiry, and post-inquiry. These phases are described next, with examples from a range of classrooms.

Pre-inquiry activities. These are whole class activities that serve to activate prior knowledge, introduce the purpose of the investigations, and provide children with the task framework. In an earlier study (Samarapungavan et al., 2008), we showed a number of different pre-inquiry activities involving class discussion about the nature of science, inquiry tools, and generating questions and predictions about caterpillars and life cycles. Here, we use an example from the discussion in Ms. Tarkington's class associated with activities in the "What is Science?" unit. The key to symbols used in the transcripts is in the Appendix.

Taught in the first month of kindergarten, the unit started with the teacher introducing children to the idea of science as the study of the world around them. She then asked children to share what they thought science was. A few children mentioned science or technology topics and processes. For example, one boy mentioned energy ("It's where you take science and energy . . . even the road // and the energy, buildings, and all that fun stuff."). Another boy suggested that one could study the sun, moon and stars. A girl noted that science was about looking for things ("It's something that you look for!"). The teacher scaffolded the discussion and introduced the idea of science as asking and trying to answer questions about the world. Throughout the unit the teacher emphasized the social and intersubjective dimensions of science by encouraging each child to contribute to the discussion, by recording children's contributions on the idea board, and referring back to these contributions as the unit progressed. As children participated in the process of doing science, they also communicated their developing concepts of themselves as scientists. This was a theme that was emphasized across the SLP unit activities. The excerpt provided here is from the early part of the discussion (September 19, 2006):

Ms. Tarkington: Today we are going to talk about something that it's a big word//We're going to talk about SCIENCE.
Children: Science?
Ms. Tarkington: Science.
Children: Science!
Ms. Tarkington: Raise your hand if you've heard that word before?//
Science is the study of the natural world around us. You know that scientists, they study everything around us//
Caleb: Even the sun.
Ms. Tarkington: Even the sun!
Caleb: And the moon!//
Ms. Tarkington: What else do you think science is?/
Dale: I was watching Spiderman and I saw science.
Ms. Tarkington: What did you see science on Spiderman? What did you see? What were they doing?
Dale: They were talking to Spiderman!
Ms. Tarkington: So maybe science could be something about communication? Talking with each other?// Ok, let's say that science . . . we're going to make a web today . . . let's say (writes on the idea board) that science involves talking with other people//
Karen: You have to look for things that are really big . . . it's really, really big, like that (points to computers in room)
. . . and maybe small.
Ms. Tarkington: OK, look for big and small things (writing on idea board)//
Dale: Ms. T., I am a scientist! You know why? 'Cause I have binoculars, like you said.
Ms. Tarkington: Binoculars are a tool. They (scientists) use that.

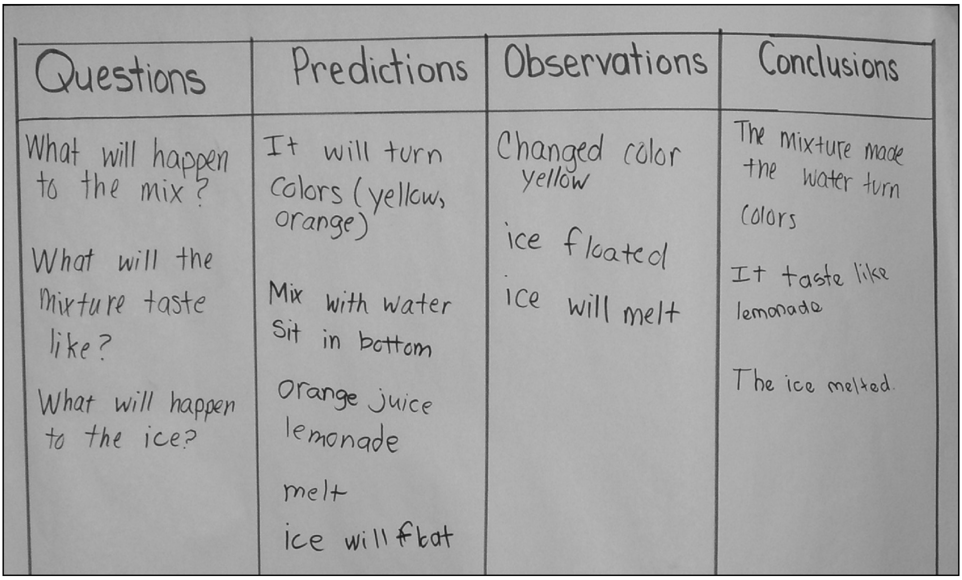


FIGURE 1 Completed idea board reflecting children's contributions during the discussion associated with activities for the unit "What is Science?"

To help children better understand these ideas, the teacher then moved to an activity involving dissolving a lemonade mix into water. This activity was selected because many children were likely to have had prior experiences with using drink mixes in their own homes, so it would give them an opportunity to draw on their prior experience and ideas to generate predictions about what would happen. Ms. Tarkington used the activity to introduce children to the idea that scientists begin investigations by asking questions, making predictions, observing, and generating notes as a way of keeping track of their investigations. She introduced the materials and engaged children in predictions about whether the powder would dissolve or not, what the color of the mix would be, what its taste might be, and whether ice would dissolve or not. Throughout the discussion, she recorded children's ideas on the idea board (Figure 1). The excerpt below is associated with this discussion (September 19, 2006).

Ms. Tarkington:	Let's put our thinking caps again. Let's look at this (points to the mix). Do you think it will turn red?
Children:	No! Yeah!
Ms. Tarkington:	I don't know, but if you think it will, raise your hand and I will put that down.
Children:	(raising hands) Orange. . .
Ms. Tarkington:	If not . . . I heard, orange, . . . (m).
Children:	Yellow . . . blue . . . red.
Ms. Tarkington:	Ok, I heard, yellow and red are some good colors I heard.
Bob:	And blue!

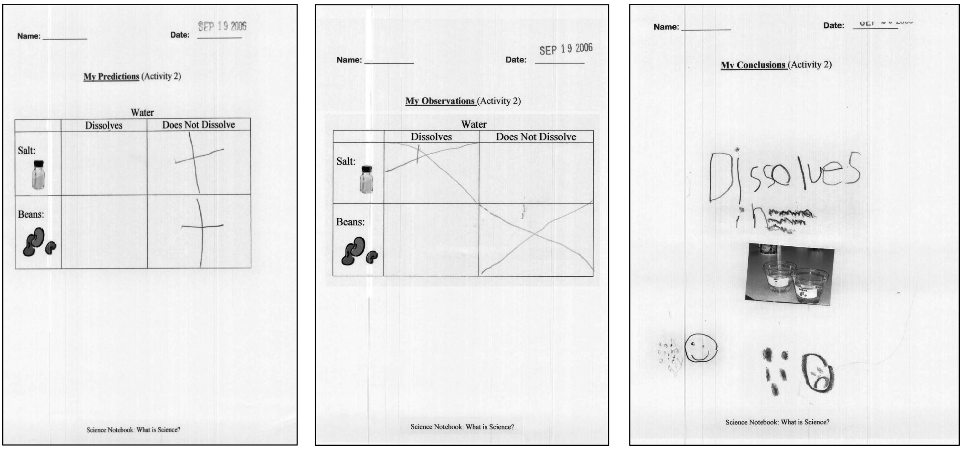


FIGURE 2 Predicting whether salt or beans will dissolve in water, then recording the observations and summarizing.

Ms. Tarkington: Ok. (records ideas on the board). What else do you think will happen to the mixture? You think anything else is going to happen? Yes? (points to Anna)

Anna: It will turn . . . (inaudible)

Ms. Tarkington: Will it be powder?

Anna: It will turn into lemonade.

Ms. Tarkington: It will turn into lemonade. Do you think that it will dissolve?
That [it will mix into the water?

Anna: [yeah, yeah, yes.

Ms. Tarkington: You think so? Or will we just have a whole bottom filled with powder?

John: A whole bottom filled with powder!

Ms. Tarkington: You think so?

Ella: I know!

Ms. Tarkington: Well, that's something that we have to look very carefully at. 'Cause Anna, Anna thinks the mix . . . it will mix in with the water (writes on the board) all right? So Anna is going to say that it's going to mix with the water and then I have some other friends that think that it's going to sink in the bottom, that it's not going to mix in (records on idea board). All right . . . (m.
Let's look at our next question.

As the teacher scaffolded children's predictions, she emphasized the importance of careful observation ("we have to look very carefully"). Then, in the lessons following the pre-inquiry activity just described, the children moved to an inquiry activity in which they explored, recorded, and discussed what happened to salt and beans when they were each put into water. An example from the notebook pages associated with these activities is shown in Figure 2. In addition, children extended their understandings by reading and discussing the book *Science is Everywhere* (Yu, 2006). An excerpt from this book reading is provided under *Literacy Activities.*

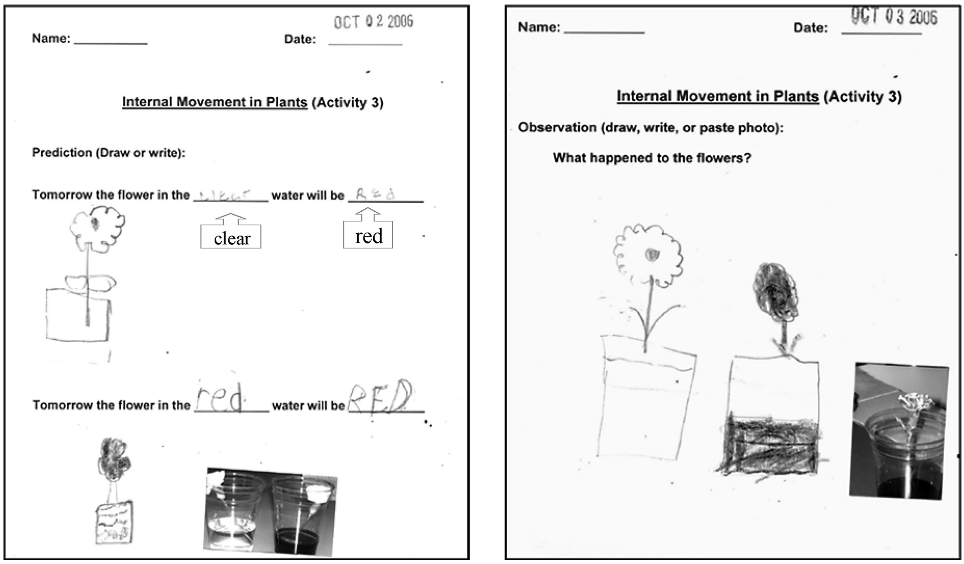


FIGURE 3 A student's prediction of the appearance of white flowers in clear and colored water and observation recorded the following day (inserted arrows indicate what the student wrote in the blank spaces).

Inquiry activities. These comprised sets of small group activities during which children conducted their investigations. During the inquiry phase children asked questions, made decisions about what, how, and when they might conduct observations, collected and recorded data in their science notebooks, and drew conclusions. For example, in the Living Things unit, teachers discussed with the children the results of an activity intended to help them understand that plants have internal movement by studying the movement of water through carnations. In the pre-inquiry phase of this unit, children brainstormed about the living things that they were familiar with and discussed how one might tell whether or not something was a living thing. They learned that living things had self-initiated movement. Then, in the inquiry phase, to help the children understand that plants, as living things, have internal movement, teachers guided children through the investigation with carnations. Children did the activity in small groups. At the start, groups were given two white carnations, each in a cup of clear water. Each child drew a picture or pasted a photo of the white carnations in their science notebook. Next, concentrated food coloring was added to one of the two cups; the water in the second cup was left clear. The next day the children made observations and recorded in their notebooks what happened to the carnations. An example of a prediction and an observation, taken from a child's notebook entries, is shown in Figure 3.

In the excerpt shown here, the teacher (Ms. Barr, October 5, 2006), helped children record observations at the conclusion of the investigation and then compare them with predictions they had made the previous day.

Ms. Barr: How many, in your science notebooks, do you remember—how many of you predicted that it would still be white? (some children raise their hands). Some of you predicted that. Okay, we're going to be looking in our science notebooks and we're going to see, we're going to remind ourselves, what did we predict? Okay, no:::w, Ms. Nelson (the classroom assistant) is going to pass out the carnations that were put in with red food coloring. (pause, while Ms. Nelson places the cups with carnations in red water onto each group of tables).

Kami: (Looking at the flowers in the nearest cup) Ooo, look, there's a flower.

Ms. Barr: There is a little bud there, right . . . (m). Who can raise their hand and tell me what happened? Robert, what happened?

Robert: Um, it turned red.

Ms. Barr: They turned red! So, does this show you that inside the plant there is movement? (demonstrating with her hands) Is it moving all the way up to the top? (pause) Does that tell us it does do that?

Children: (chorus) Yeah //

Ms. Barr: We are going to get out our science notebooks, and we are going to color the color that it turned. What color is it now?

Children: Re:::ed.

(Science notebooks are handed out to each child. As the children draw the flower they observe, the teachers move around the room and talk with the children individually).

Ms. Barr: (to Mark) What was your prediction? (to the group) Mark said he had it, let's look. Oh, you said it would be red. Very good. Awesome. Cara, did you predict it would be red? Do you remember?

Cara: (turns back a page of her notebook) Yellow.

Ms. Barr: Yellow, okay. But you colored it pink. James, what did you think would happen? (James's response is inaudible) Purple?

Post-inquiry activities. These activities provided the children with opportunities to review and share what they had learned with the class. The excerpt shown here is associated with the activities in the Living Things unit (October 23, 2006). The large group activity was led by Ms. Baldwin, the student teacher in Ms. Burke's room. The session began with Ms. Baldwin engaging children in a discussion about the living things that they were learning about. During the discussion, the teacher and the children referred to a large poster that they had created with pictures of plants, insects, and animals, and words that described the characteristics of living things (Figure 4).

Ms. Baldwin: And so what are all those things? (pointing to the poster) Are those things alive?

Children: Yeah.

Ms. Baldwin: Why are they alive?

Children: (Raising hands) because, because. . .

Katie: Because they are living!

Ms. Baldwin: Because they are living, so those are living things. And why are they living, Janet?

Maria: Because [they take care of themselves.

Janet: [They eat food.

Ms. Baldwin: They eat food. . . And Tyree, what is something else that they do?

Tyree: (pointing to picture of cattails on idea board) Cattails live!

FIGURE 4 Living Things unit: Post-inquiry discussion poster created from images that the children collected and photographs taken during the Nature Walk Activity in Ms. Burke's class.

Teacher: Cattails live. Maybe we can look at our chart to see what they do. Somebody already said that they eat. What else do they do?
Trisha: (very quietly) [They grow.]
Eduardo: They, they. . . [They excrete.]
Ms. Baldwin: They what?
Eduardo: They excrete!
Ms. Baldwin: You remembered the word, awesome! What else do they do?
Evan: They grow.
Ms. Baldwin: They grow. Fatima?
Fatima: They walk.
Ms. Baldwin: They walk, or they move. . .

Katie: Or jump!
Julian: [Or, or!
Alex: [They can fly!

In the next section, we outline and illustrate the literacy activities that occurred concurrently with the inquiry activities.

Literacy Activities. We incorporated literacy through both writing and reading activities. Children's use of written language was supported through the notebook activities and the idea boards that the teachers used to document classroom discussions. Depending on the activity, children represented their ideas through a variety of different strategies such as drawing pictures, pasting photos, using checkmarks, dictating text to adults, pasting in word labels, copying words from the classroom's word wall, and using invented spelling. These different forms of literacy are illustrated in the examples of notebook pages included in this article. The science notebook pages were typically relatively unstructured, to allow flexibility in how children represented the information.

Reading skills were supported in the context of each unit's activities through shared book reading. We used informational texts throughout the intervention for at least two reasons. First, literacy experiences in kindergarten already include an abundance of fictional texts and there are concerns that these texts alone do not provide children with the skills needed to understand the non-narrative, expository text that they will encounter later (Doiron, 1994; Duke, 2000). Second, studies (e.g., Caswell & Duke, 1998; Pappas, 1991; 1993) have shown that informational text is equally interesting and motivating to young children as is fictional narrative. Thus, we reasoned that rich experiences with nonfictional texts were needed to facilitate not only the development of literacy but to also provide insights into the processes of knowledge acquisition within specific disciplinary content.

The readings were selected from a pool of grade-appropriate, non-fiction children's books related to the science content of each unit. These books were evaluated for accuracy, quality, and currency of content, realistic portrayal of time, race and gender equity, quality of illustration, and distinguishability of fact from fantasy (Mayer, 1995; Rice, 2002). Book selections were made following discussions with the teachers who had trialed sets of books in the classroom during the first year of the project. The books used in each unit are listed in Table 1.

During the book readings the teachers used dialogic reading strategies (Wells, 1999; Whitehurst et al., 1999) to activate children's prior knowledge, promote comprehension (including by building vocabulary), make linkages between the reading and inquiry activities, and facilitate connections with children's experiences. Use of these practices facilitates insights into the functions and structure of language as the children describe, explain, justify, and summarize. Competence in the use of these language functions is central to the development of scientific knowledge (Halliday, 2006; Norris & Phillips, 2003; Yore, Bisanz, & Hand, 2003).

Next, we illustrate typical aspects of the discourse that was generated during the reading sessions. We provide examples from three different teachers and readings associated with three different units.

Excerpt 1. Reading of "Science is Everywhere"—What is science? Unit (September 26, 2006). This reading was conducted during the first week of the SLP, after the children were introduced to the idea that science is the study of the world around us and that scientists study the world by making predictions, conducting observations, and drawing conclusions. As noted in the excerpt associated with the section on pre-inquiry activities earlier in the article, these ideas were explored through an investigation about dissolving. Children also read *Science is Everywhere* (Yu, 2006), an information book that provided examples of science in children's everyday worlds through sections about science in the kitchen, science in the back yard, and on the sidewalk. During the reading the children were guided to ask questions and make predictions about each subtheme. For example, in the first part of the book, children were guided to make predictions about dissolving using lemonade mix, water, and ice—a topic that paralleled the science inquiry classroom activities. Thus, in reading the book, teachers scaffolded connections between the content of the reading and the dissolving activity that the children had done in the classroom. The goal throughout the reading was not to teach children about the chemical processes involved in creating a solution (science in the kitchen), or in rusting (science in the back yard), or in evaporation (science in the back yard). Rather, it was to encourage children to generate predictions using their prior knowledge and personal experiences.

The excerpt provided here is associated with the second subtheme in the book (science in the back yard). The dialog demonstrates the ways in which the teacher scaffolded children's predictions, as well as children's use of familiar experiences with rusting as they predicted whether objects shown in the book would or would not rust.

Ms. Tarkington:	"MAKE A PREDICTION! WHICH OF THESE THINGS WILL RUST?" Make a prediction, raise your hand if you think the wooden train will rust.
Herman:	My mom's truck.
Ms. Tarkington:	A wooden train? . . . (m . . .) will the wooden train rust, Karen? What do you think?
Karen:	That will rust. (points to tin can in the book)
Ms. Tarkington:	What do you think about the wooden train?
Karen:	No. (shaking head)
Ms. Tarkington:	What are you pointing to that will rust?
Karen:	(Points to tin can in the picture) This will rust!
Ms. Tarkington:	You think this (points to tin can) Karen, will rust?
Karen:	(Nods positively)
Ms. Tarkington:	What about the plastic clothes pin? Bob, what do you think?
Bob:	It won't dissolve!!
Ms. Tarkington:	What about rust?
Bob:	No!
Ms. Tarkington:	No? I don't think so either. What about the plastic bottle?
Children:	N:::o!
Ms. Tarkington:	Salina doesn't think so.
Ms. Tarkington:	What about the paper clips?
Children:	(all together) No:::o.
Ms. Tarkington:	What makes you think that the paper clips will rust but not the plastic bottle?

Alysa: The plastic bottle won't rust, only this (points to tin can) and these. (points to metal paper clips)
Ms. Tarkington: Why do you think the paper clip will rust and not the plastic bottle?
Alysa: The plastic bottle is plastic and it won't rust!
Maria: The plastic bottle is plastic!
Alysa: It's a bottle!
Ms. Tarkington: So, you don't think plastic will rust?
Alysa: No, it doesn't rust!
Ms. Tarkington: Ok, What about nuts and bolts? You think they'll rust?
Children: (excited noise and raised hands!)
Ms. Tarkington: Have you been out to your dad's garage and maybe looked at a bolt on something? Maybe a bolt on your mom's car?
Bob: Oh yeah! I saw one, I saw one!
Maria: It was rusty on my car!
Teacher: Ok, so maybe the bolt was rusty, So that tells us (inaudible) will rust.
Bob: I saw rust in my garage!
Ms. Tarkington: Ok (turns page) you guys were right! You got all of them right!
Kane: The train didn't rust!
Ms. Tarkington: Good job! All right!//

Excerpt 2: Reading of "Force and Motion"—Motion unit (November 29, 2006). This reading was associated with the inquiry phase of the unit on Force and Motion. The classroom discussion centered on differences in movement between living and non-living things, with examples noted on an idea board. Classroom activities included simple experiments about friction following predictions about which of two identical toy trains traveling down a smooth or rough surface would reach the ground first. The teachers created the experimental contrasts for the children by setting up two ramps of identical slope and length. One ramp had a smooth surface and the other had a rough surface. Children were asked to predict on which of the ramps identical trains released simultaneously would come down first. The children then took turns in pairs to run data trials by releasing the trains at the same time from the top of the ramp to the count of three. The remaining children in the group observed the outcome of each trial and told the teacher what they observed. The teacher then recorded the outcome on the idea board (see Figure 5) and then proceeded with the next trial. After each group had completed five trials, the children used the data sheet to discuss what they had observed and whether or not it was consistent with their predictions.

Prior to the book reading, the children generated examples of push, pull, and lift, and discussed gravity as a force that is always "pulling down." In addition, the teacher (Ms. Donnely) reviewed with the class different ways to use force in order to make things move. Following this discussion, Ms. Donnely invited the children to sit in the rug area for reading. She had prepared a big board with the letters "otion" on it, and used the book as an opportunity to review the letter "M" and to revisit concepts that had been discussed during the inquiry activities.

Ms. Donnely: We are going to hear these words today (push, pull, lift, force, motion) . . . we are going to be reading another book today, another science book. Ok, boys and

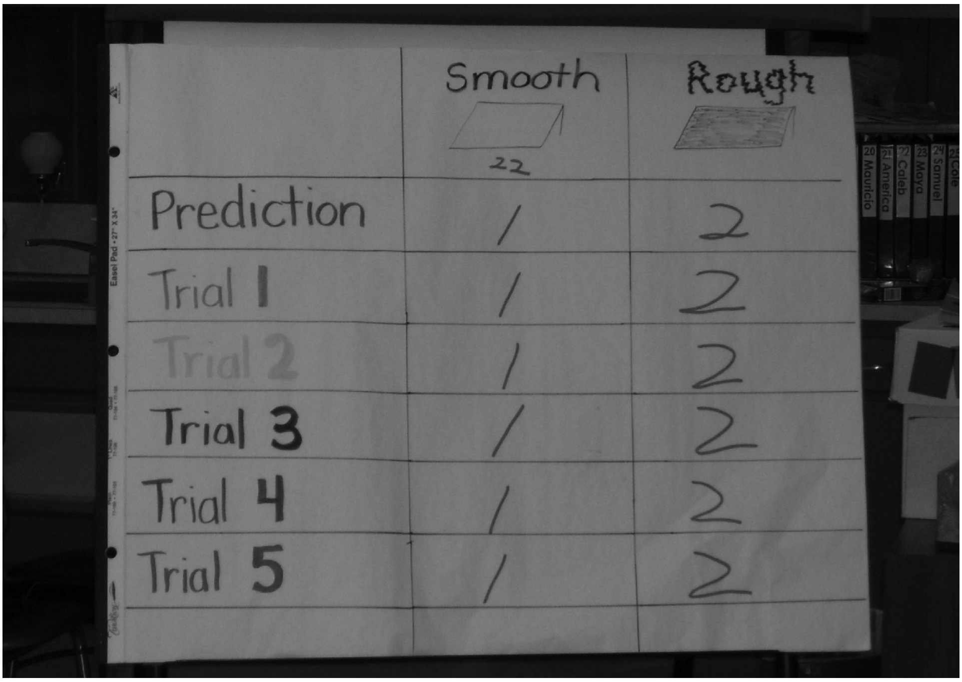


FIGURE 5 Idea board documenting children's predictions and findings after two identical trains were released on a smooth and rough ramp.

girls, let's come on over, please push in your chairs. Gravity is pulling everybody down, right? And you are all moving right now, you are all IN MOTION! //

Alex: (jumping excitedly as she is moving to the reading area) We are in motion!

Ms. Donnely: . . . (m) Now, I have not finished the word this morning that I have written up here (points to big board), and I want to write the word MOTION. Now, . . . (m), I am missing the first letter. This just says OTION. I want this to say M:::MOTION. What letter do I need to put right there?

Children: eM!

Ms. Donnely: Em! Because em says what?

Children: Motion!

Ms. Donnely: It says, What does the letter M say?

Children: M:::M

Ms. Donnely: Very good.

Kaleb: M:::otion, it said it, motion!//

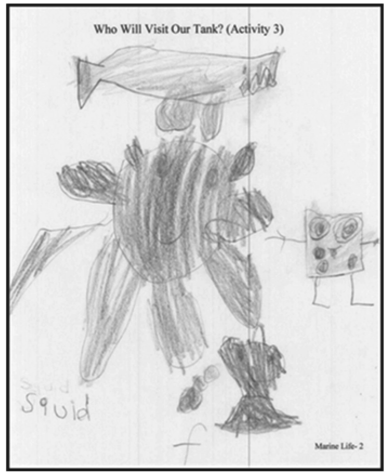
Ms. Donnely: (reading) "A STRONG FORCE WILL MAKE AN OBJECT MOVE FAST AND FAR. A GENTLE FORCE WILL MAKE AN OBJECT MOVE SLOWLY AND A VERY SHORT DISTANCE."

	Okay, now, "WHICH BALL," the boy here in the blue and yellow (points to boy in one picture), the ball he's kicking, or the boy in the red and black? "WHICH BALL WILL TRAVEL FARTHER?"
Children:	The red and black, the red and black, the red and black.
Ms. Donnely:	Okay, raise your hand if you can tell us why the red and black. (several children raise their hands). Valeria?
Antonio:	(inaudible)
Ms. Donnely:	Valeria?
Valeria:	'Cause he's pushing it harder!
Ms. Donnely:	Okay, and we can tell that because . . . (points to picture)
Valeria:	He's pushing with the foot and it's in the back.
Ms. Donnely:	His foot is way back and it looks like he's running, doesn't it? And he is just trotting alongside the [ball (points to other picture)
Kaleb:	[Slowly!
Ms. Donnely:	Yeah, he is kind of moving slo:::owly. Right. But he is running and he's got his foot back (motions) and he is really going to put that foot forward and he is BOOM, he's going to hit that ball really hard. So this ball is going to go farther.
Martha:	And go right into the shoot!

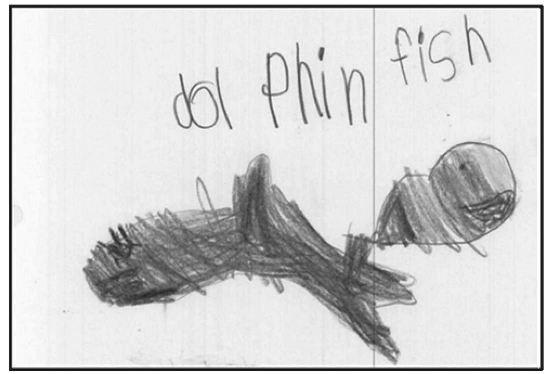
Excerpt 3: Reading of "What is an Ocean?"—Marine Life unit (February 12, 2007). This reading was associated with activities designed to introduce children to the idea of the ocean as a habitat for living things. In the following excerpt, Ms. Cannon used questioning strategies to activate children's prior knowledge about aspects of the ocean that were discussed during the pre-inquiry phase of the Marine Life unit. During the reading children defined new words, and made connections to the saltwater aquarium in their classroom, as a model of the ocean. As part of the activities associated with this unit, children also made predictions in their notebooks about what would live in their saltwater aquarium; it contained just water at that time. Examples of children's drawings from these activities are shown in Figure 6.

Ms. Cannon:	Well the story we're going to start out with is "WHAT IS AN OCEAN?" What is an Ocean? . . . What do you think it is?
Jesus:	It's. . .
Ms. Cannon:	Here we go, what's an ocean?
Jesus:	When it has water. . . (inaudible)
Ms. Cannon:	Aha. The ocean has lots of water.
Dora:	And it has whales and sharks and pebbles and it has lots of fishes.
Ms. Cannon:	Ok.
Iriana:	(Inaudible)
Ms. Cannon:	(acknowledging Iriana's response) These are all true! Yes, Peter?
Peter:	And it got big waves (makes wave motion with hands).
Ms. Cannon:	Wow! Carla?
Carla:	Sharks! Fish!
Ms. Cannon:	We know a lot already! Eduardo?
Eduardo:	(Inaudible)

Peter: Starfish, fishes, plants, blowfish



Alysa: Squid, Spnge Bob



Dora: Dolphin, fish

FIGURE 6 Marine Life unit in Ms. Cannon's class: Student predictions about things that can live in an aquarium.

Ms. Cannon: (teacher repeats child's statement) There's fish in the ocean?
Eduardo: Aha.
Ms. Cannon: Dana?
Dana: (inaudible)
Ms. Cannon: What, sweetie, what? Aha, all kinds of fish! //
"WHAT DOES AN OCEAN LOOK LIKE? AN OCEAN IS A HUGE AREA OF WATER."
Huge. What does huge mean?
Children: It means it's . . .
Ms. Cannon: Please raise your hand. Patrick?
Patrick: It means it's really big.
Ms. Cannon: It's really big! Really, really, really big! When you look out over the water, you cannot see any land on the other side, because it's so big!
"THE OCEAN IS SALTY. AND YOU MAY FEEL THE SALT ON YOUR SKIN." Do you know any water in here that is salty? (children raise hands). Where, Peter?
Peter: Aquarium.
Ms. Cannon: Our aquarium, yes, our fish tank. Those are special fish that live in salt water. Do we drink salt water?
Ms. Cannon: No:::o!
Alysa: And it's disgusting!

Implementation of Science Activities in the SLP Classrooms

At the start of the project, the teachers were unfamiliar with inquiry-based teaching but were interested in learning more about it. During Year 1, the three authors met on several occasions with the teachers to develop shared understandings of what it means to teach and learn science, and to construct a framework for project implementation. In addition, the teachers implemented activities associated with the development of two units and provided feedback to the authors. Year 2 SLP activities were planned jointly with the teachers during meetings held at the conclusion of Year 1.

All SLP teachers in School 1 and one of the two SLP teachers in School 2 had participated in the development and pilot implementation of lessons the previous year (Year 1). However, one teacher who had participated in the study during Year 1 moved away from the area, and therefore we worked with the new teacher (Ms. Tarkington) who was hired to replace her.

The teachers were provided with the materials and a set of teacher guides that: (a) described the instructional goals for each unit as well as the inquiry and literacy activities (in sequence); (b) included specific examples for implementing the SLP activities and scaffolding children's discussion and learning; and (c) provided relevant disciplinary content for each activity (e.g., properties of living things, biological adaptation). The teachers were also provided with links to websites with additional information on various life science topics.

Each teacher was assigned a classroom assistant (a member of the SLP project team) to help with the implementation of the intervention. Prior to the implementation of activities in both schools, we conducted an after-school workshop with the SLP teachers. This workshop served as a follow-up to the Year 1 workshop and meetings about implementing SLP with teachers throughout the year. It covered the principles of SLP, and provided an overview of SLP activities, readings, and materials for the units. In addition, we discussed a range of instructional and management strategies for teachers, involving use of activity centers, reading non-fiction text and asking higher-order questions, incorporating unit activities within existing classroom routines (e.g., calendar time), eliciting students' questions and ideas, general student-centered strategies, and adapting literacy activities (e.g., writing in notebooks) to individual students' development. We conducted additional individual meetings with Ms. Tarkington, the teacher new to SLP.

Over the course of the year, SLP teachers, assisted by the SLP classroom assistants, implemented the science inquiry and literacy activities. Science lessons were videotaped and lasted approximately 60 minutes, twice a week. During the unit implementation phase, members of the research team had after-school meetings with the teachers to discuss how the implementation was working, record suggestions for future revision, and address issues that arose during the course of implementation. Additionally, teachers and classroom assistants used e-mail communications to address ad hoc issues or concerns that arose during instruction (for example, requests for additional content information).

Fidelity Data. After each SLP lesson, the classroom assistant rated the teacher's implementation of the SLP inquiry and reading activities using separate inquiry and reading fidelity rubrics. Their ratings were done as soon as possible after the lesson was completed and the assistant had left the classroom. Fidelity rubrics were collected for approximately 180 SLP lessons (6 classrooms × 30 lessons, across the 5 units). The rubrics included a rating scale across a number of relevant criteria (explained next) and space for the raters to note examples that supported each of the ratings.

Two of the authors, one for each of the inquiry and reading activities, provided fidelity rating training for classroom assistants at the beginning of Year 2. Training sessions involved iterative cycles of defining categories, watching videotaped lessons from Year 1 taught by different teachers, completing rubrics independently, and evaluating and discussing ratings. These iterative cycles continued until each assistant achieved inter-rater agreement with the standard (i.e., the author leading the training) that was consistently greater than 80%.

Fidelity of inquiry activities. The rubric for fidelity of the inquiry activities documented teacher behaviors and student participation. Specifically the observers rated the teacher's: (a) explanations and modeling of target concepts; (b) scaffolding student participation through questions, suggestions and responding to children's ideas; (c) scaffolding use of inscriptional tools during the activities (e.g., idea board/science notebooks); and (d) scaffolding use of SLP manipulatives. Student participation during the activities was also rated. We used a 3-point rating scale: 0 indicated that the criterion was not met, 1 indicated that the criterion was partially met (e.g., there was not sufficient follow-up), and 2 indicated that the criterion was fully met.

We averaged the scores for each teacher across each criterion for all inquiry lessons. The findings for each classroom are shown in Table 3. Overall, the data indicate that all teachers implemented the SLP activities, albeit with some variability. On average, teachers modeled or explained target concepts, scaffolded student participation with questions or responses, scaffolded the use of inscriptional tools and manipulatives, and elicited student participation at least partially as intended.

TABLE 3
Mean Fidelity Ratings for the SLP Inquiry Activities across Five Units

		*Inquiry Fidelity Criteria**					
Classroom	*Teacher*	*Models/ Explains*	*Scaffolds Participation*	*Inscriptional Tools*	*Manipulatives*	*Students Participate*	*Grand Mean*
1	(Ms. Donnely)	1.8	1.8	1.9	1.7	1.9	1.8
2	(Ms. Cannon)	1.5	1.1	1.7	1.7	1.5	1.5
3	(Ms. Barr)	1.4	1.5	1.7	1.3	1.8	1.5
4	(Ms. Barr)	1.5	1.5	1.7	1.3	1.8	1.6
5	(Ms. Burke)	1.4	1.3	1.2	0.9	1.3	1.2
6	(Ms. Tarkington)	1.7	1.7	1.2	1.5	1.6	1.6

Note. **Inquiry Fidelity Criteria*

Models/Explains:	Teacher models/explains target concepts
Scaffolds Participation:	Teacher scaffolds students' participation by encouraging questions and responding to children's ideas
Inscriptional Tools:	Teacher scaffolds use of inscriptional tools (idea board/science notebook)
Manipulatives:	Teacher uses SLP manipulatives appropriately
Students Participate:	Students participate actively in class discussion

Fidelity of reading activities. Classroom observers rated the implementation of the reading activities using an adapted version of the Teacher Reading Behavior Checklist (Powell & Diamond, 2005). The rubric included the following teacher behaviors: (a) providing background information prior to the book reading; (b) asking close- and open-ended questions intended to promote understanding of the material and to provide linkages between the content and children's experiences; (c) scaffolding connections between the reading and children's experiences with the inquiry activities; (d) defining new science vocabulary; (e) acknowledging and responding to children's questions or comments; and (f) children's interest and engagement during the reading. We used the same 3-point rating scale, described for the fidelity of the inquiry activities, to rate the extent to which the criteria under consideration were met. Ratings were averaged for each teacher across the SLP reading sessions for each criterion; results are shown in Table 4.

The fidelity patterns for the SLP reading activities parallel those for the inquiry activities. On average, teachers introduced the book by connecting it to the inquiry activities, asked open- and closed-ended questions, defined novel science words, and connected children's questions or comments to the book at least partially as intended. Asking questions to promote connections between the book and children's experiences was, on average, less than criterion, due to very low occurrences by one teacher (in two classrooms).

Comparison Classroom Science Activities. Information about the science activities in the comparison schools was obtained from classroom observations and teacher interviews. We videotaped, and later transcribed, two different science lessons in each class, selected by the teachers as being typical for them. We also conducted semi-structured interviews with teachers at the end of the school year to investigate aspects relating to their instruction, especially in science (e.g., What do you do for science in kindergarten? How do you figure out what to do and how

TABLE 4
Mean Fidelity Ratings for the SLP Reading Activities Across Five Units

		*Reading Fidelity Criteria**							
			Questions						
Classroom	*Teacher*	*Introduces*	*Closed-Ended*	*Open-Ended*	*Relate*	*Novel Science Words*	*Responds*	*Interest/ Engagement*	*Grand Mean*
1	(Ms. Donnely)	1.9	1.5	1.7	1.6	1.0	1.6	1.8	1.6
2	(Ms. Cannon)	0.9	1.4	1.3	1.4	1.2	1.1	1.6	1.3
3	(Ms. Barr)	1.7	1.4	1.7	1.1	1.2	1.9	1.9	1.6
4	(Ms. Barr)	1.7	1.7	1.6	1.1	1.5	1.4	1.9	1.6
5	(Ms. Burke)	1.3	1.7	1.1	1.4	1.6	1.4	2.0	1.5
6	(Ms. Tarkington)	1.6	1.8	1.0	1.4	1.5	2.0	2.0	1.6

Note. **Reading Fidelity Criteria*

Introduces: Teacher provides background information, connects the book to SLP activities
Closed-Ended Questions: Teacher asks one or more closed ended questions about the book
Open-Ended Questions: Teacher asks one or more open-ended questions about the book
Relate Questions: Teacher asks questions intended to help the children relate the information to other experiences
Novel Science Words: Teacher engages children in a discussion about the meaning of a new science word
Responds: Teacher acknowledges and responds to children's spontaneous comments or questions during the reading
Interest/Engagement: Children's interest and engagement during the book reading activities

much time to spend?). The interviews lasted approximately 40 minutes, were audiotaped, and transcribed. In the current section we use these data to provide a descriptive account of the regular kindergarten science lessons that children in the comparison classrooms experienced.

The teachers in the regular kindergarten classrooms were very positive about science; they reported they enjoy it personally, and tried to work it into their curriculum when they could. A heavy emphasis on literacy, and on math to a somewhat lesser degree, made this difficult. Nevertheless, many of the weekly themes or topics the teachers chose were science-related and the children usually had some science each week, using materials provided either by their respective schools or by the teachers themselves.

Teachers told us that providing hands-on science learning was an objective for them. They decided individually what science they taught, and made decisions according to what they thought children would be interested in or what they themselves had enjoyed in previous years. Teachers reported lists of different topics they covered, often in the context of cultural or seasonal events (e.g., apples and trees in the fall, pumpkins at Halloween, teeth during dental health month, and butterflies and plants in the spring). Other topics they recounted were insects, marine life, the seasons, the five senses, and staying healthy. Activities they described include comparing two plants (one placed in the light and one in the dark), using marshmallows and pretzels to make spiders (to learn that spiders have eight legs) or cookies and twizzlers to make insects (showing three body parts and six legs), cooking, and making grass people with grass seed planted in a cup.

The teachers also reported they sometimes integrated science with other subjects: the reading program one teacher used included some science books (e.g., "Bee Facts"), children did sorting while learning about the food pyramid, they wrote about science topics (e.g., animals in the ocean, fire safety), teachers read books (often fiction) about the topic, and sometimes a movie or play allowed connections with science (e.g., talking about crabs after watching "The Little Mermaid"). Of the six lessons we observed and recorded, all involved hands-on activities and four of the six involved the teacher reading a book or telling a story on the topic. An outline of the different lessons (their topics, activities, and books) is presented in Table 5. We asked to observe two connected lessons, if teachers continued with a topic beyond a single day. Four of the lessons were stand-alone, whereas another spanned two days. The two-day activity involved children making saturated solutions and placing snowflake shapes in them, then removing the crystallized snowflakes four days later. This latter activity involved the only lessons that came close to inquiry. Furthermore, the topic shares similarities with the SLP inquiry activities in which children investigated dissolving, first with lemonade mix, and then with beans and salt, as described in the section on pre-inquiry activities associated with the "What is Science?" unit (Table 1). Therefore, to highlight similarities and differences between this and SLP activities, we briefly describe these snowflake lessons and provide a sample of the classroom discourse from the transcripts.

The activity was conducted with small groups of children sitting around a table with an empty polystyrene cup in front of each and a box of borax in the middle of the table. Ms. Milne began by showing them a snowflake shape covered with crystals, on a string, and engaged in discussion with three boys about what it might be and how it might have been made. She then led the children through the following sequence: the teacher spooned borax powder into each cup, added hot water, had the children stir the water, added drops of food coloring, had children place the snowflake shape into the solution, and finally take their cups to the back of the room. This activity was repeated with two different groups.

TABLE 5
Overview of Science Lessons Observed in the Comparison Classrooms

Science Topic	*Activity*	*Reading*
Health & Germs	Teacher shone an ultraviolet light for class to see slime (representing germs) on 2 children's hands, then made comparisons after they washed their hands with either cold water or hot water and soap. Cut out an outline of a teddy bear, with his paw separate, then pasted the paw onto a Kleenex and the Kleenex onto the bear's nose, to show how the bear should cover its nose to stop germs from spreading.	Teacher told a story she called *How germs travel*. Not a published book.
Pollution & Recycling (on Earth Day)	Identified examples of recyclable items (e.g., juice container, pop can, tin can) presented by the teacher.	Showers, P. (1994). *Where does the garbage go*? Harper Collins.
Light & Shadows	Teacher wrote words on chart paper that children knew about shadows. After the book reading, the class compiled a list of light sources. Groups of children used their hands to make patterns with shadows on the whiteboard, using the overhead projector.	Bulla, C. R. (1998). *What makes a shadow*? Scholastic.
Teeth & Dental Hygiene	Pasted 20 mini marshmallows onto 2 arcs drawn on paper to represent two rows of teeth. Teacher demonstrated how to brush teeth, using large toothbrush and a model of a tooth. Teacher demonstrated how to floss teeth, using 2 children standing close together representing teeth.	Rowan, K. (2000). *I know why I brush my teeth*. Walker Books.
Snowflakes (2-day lesson)	Grew crystals on snowflake outlines from a saturated borax solution with food coloring added. On the second day children removed snowflakes from the solutions. This was followed by a whole class summary of the activity.	

We observed many similarities with SLP activities. Ms. Milne asked open-ended prediction-type questions, (e.g., "What do you think's going to happen to the powder when we put the water in?" "What do think's going to happen when we put one drop [of food coloring] in the water?"). She asked children for their ideas, and responded with other questions rather than providing them with correct answers, as shown in the following transcript that begins at the start of the activity (March 1, 2007):

Ms. Milne: (showing 3 boys a completed borax-crystal snowflake) What do you think this is?
Tim: Soap.
Ms. Milne: Does it feel like soap? (Tim and Chris feel it).
Tim: Rock.
Chris: It's diamond rock. (Pause) It feels like diamond rock.
Eric: Hey, is this one like sugar stuff? (Pause) Hey, is this like, um, like, um, stuff that you're not 'posed to touch, like are made for pools? Like chemicals?
Ms. Milne: Do you think so, huh?
Eric: Sometimes they give us chemicals in little bouncy balls, but they're not bouncy balls. But we have to throw them away because we're not allowed [inaudible].

Ms. Milne: Ok. So you think it might be something like a chemical? (Pause) But if we started out with the powder (points to borax box), how does it turn into these hard rocks and crystals?

Eric: Because they go hard and they grow even bigger and they get hard, like they're growing in ice. (Teacher asks something inaudible). It keeps on growing. If you leave it alone it'll get even bigger and bigger.

Ms. Milne: You think it'll get bigger and bigger if we just leave it alone?

Eric: Sometimes people leave their stuff out in the snow, by their [inaudible] and they let 'em get all frozen.

As the transcript also showed, the children related their own experiences to the questions raised.

There were considerable differences between this lesson and those within the SLP. Noticeably, there was no language of science used. The lesson was not labeled as "science"; indeed, the discipline was not named in *any* of the regular science lessons we observed. Although the teacher asked children to make predictions and directed their attention during the observations (e.g., "Look inside your cup once you've got your water in there. What happened to your powder? Is it still there?"), those processes were not labeled as such or recorded for later reference. Despite the science content and processes inherent to the activity, they were not made salient by the teacher. After the opening discussion, recounted in the previous paragraph, and some brief discussion about the color of the solution, Ms. Milne said, "Okay, do you think we should make some snowflakes?" which they then began to do. When the children later removed their snowflakes from the solution, the teacher referred to the activity as "making snowflakes" and the discussion centered on recounting the steps they took to produce them. Our impression was that the children saw these lessons solely as an art activity. Thus, the disciplinary integrity of the science activity was not evident. This was the case for the other science lessons. For example, teachers engaged children in discussions that helped children make personal connections with the content of the activities. However, we found no evidence that the activities were organized around coherent science themes and ideas that the children revisited and built on throughout the year. The descriptions of teachers' science lessons, and our observations, appear consistent with published accounts (e.g., Dickinson & Young, 1998) of typical science instruction in elementary school.

MEASURES AND PROCEDURE

Children's Science Narratives

The narrative data examined in this study were obtained from open-ended interview questions during the administration of the *Puppet Interview Scales of Competence in and Enjoyment of Science* (PISCES; Mantzicopoulos & Patrick, 2007a), an individually administered measure that assesses young children's motivational beliefs through the use of puppets to promote children's interest and engagement. Similar formats have been successfully used in other research on children's self-beliefs and social cognitions (Eder, 1990; Mize & Ladd, 1988; Nolen, 2001).

The administration procedure is outlined in Mantzicopoulos et al. (2008), and it involves showing the child a set of five ethnically diverse puppets that match the child's sex. The examiner explains that the puppets will talk about different things that happen in school and asks the child to choose a puppet (Puppet 1) that is most like him or her. The child names the puppet and the examiner helps the child write the puppet's name on a tag that is then attached to the puppet. Then the examiner chooses an identical puppet (Puppet 2) from a second set of puppets (out of the child's view) and says:

> Here is another child just like you and ___________ (Puppet 1). He is a friend of ________ (Puppet 1). Let's give him [her] a name: What would you like to call him [her]? Ok, he [she] is ________________. And here is his [her] name tag. (Puppet 1) and ________ (Puppet 2) go to the same school and they have the same teacher. They have a teacher just like yours. They will talk about themselves and what they like. They like different things, but that is ok because they are different kids. It's ok for different kids to feel differently.

The puppets are then used in the open-ended portion of the procedure to elicit children's meanings about science. As noted next, the interview prompts varied slightly between the pre-SLP and subsequent sessions. In the pre-SLP session, we prompted for children's understandings by asking them to talk with us about what they might learn in science. In subsequent sessions we asked them to share with us "what happens" when they have science and what sorts of things they learn about. Similar prompts have been used in the research on children's experiences in school, referenced in the introduction. Our prompts asked children to draw on their personal involvement with science (rather than on generalized notions about what science means), in order for us to gain access to their situated meanings about what experiences, processes, and knowledge counted for them as science. Our interviews with the children thus served as a window into how children appropriated the social discourses associated with their science experiences.

Children's responses, along with the examiners' prompts, were recorded verbatim. We had successfully piloted this interview procedure in Year 1 (Mantzicopoulos et al., 2008) and continued to use it in this study. The interview session was terminated when children presented the examiner with messages that they had exhausted the subject (e.g., "and that's all I know!").

Pre-SLP interview (SLP group). We administered the PISCES in early September, before the onset of the SLP activities. Children's socially constructed meanings about learning science were prompted with the following scenario:

> Well, in the school where (Puppet 1) and (Puppet 2) go, they learn about numbers, and letters, and reading. They also learn about living things, how they grow, the weather, and things like that. That's called science.
>
> What do you think you'll learn about science in kindergarten? What do you think will happen when you have science? Would you tell me and (Puppet 1) and (Puppet 2) so that we can learn about that?

Mid-SLP interview (SLP group). In December, after children completed 17 lessons within 4 SLP units (What is Science?, Science Tools, Living Things, Force and Motion), they were interviewed with the same puppet format as in September. However, after being told that the puppets like different things and have a teacher who is like the child's, the children were prompted as follows:

> Do you have science in your school?" And, "You know, I am not there when you do science but I am really interested in what you do. Would you tell me and (Puppet 1) and (Puppet 2) so that we can learn about the sorts of things that happen in science?

The protocol included a list of specific prompts for examiners to use during the interview (i.e., What do you learn in science? What happens when you have science? And then what happens? What else do you do in science? Anything else?).

Spring interview (SLP and COMP groups). SLP children were interviewed after they completed an additional set of 13 lessons about Marine Life. At that time, COMP children also participated in the data collection. Both groups were asked the same questions as in the mid-point assessment (December). However, if COMP children responded that they did not have science we asked: "Do you know about science?" "If you had science in kindergarten, what do you think you might learn? Would you tell me and (Puppet 1) and (Puppet 2) so that we can learn about that?"

Children's Perceptions of What They Learn in Kindergarten. During the spring assessment, we also administered *What I learn in Kindergarten* (WILK; Mantzicopoulos & Patrick, 2007b), an individually administered measure that comprises 20 items intended to assess children's perceptions of learning about reading, math, and science in kindergarten. The examiner reads each item to the child (e.g., "in school we learn about numbers") and asks the child to indicate whether or not he or she has learned about the topic represented in the item. The measure is scored dichotomously (1 = yes; 0 = no). Factor analysis with 209 children from the SLP and comparison schools supported two broad factors: Learning about Reading and Math (Read-Math; Factor 1, $\alpha = .68$) and Learning about Science (Science; Factor 2, $\alpha = .90$). Following the factor analysis, we created scale scores by averaging scores on the items within each scale. Eight items loaded on Factor 1 ($M = .89$, $SD = .18$). Examples include: "In school we learn to count," "in school we learn about letters," ". . . about numbers," ". . . about shapes," ". . . about books." Children's responses on these items were positive, with limited variability (which accounts for the smaller alpha coefficient). In general, there was a tendency for children to report that they did learn about the math and reading activities reflected in the items of this scale. However, there was greater variability on the twelve items that loaded on Factor 2 ($M = .67$, $SD = .32$). Examples of items include: "In school we learn about how living things grow," "in school we learn how to make observations," "in school we learn how to use our science notebook." Thus, some children reported that they did not learn about science or the component content and process activities described by the WILK items.

RESULTS

Coding Scheme

We took a multilevel approach to coding the responses to open-ended questions, nesting some categories within others, rather than using five categories in one level as we had done in pilot work. We first identified which children's responses did, and did not, involve science. The following coding categories and exemplars from our previous work (Mantzicopoulos et al., 2008) guided this initial level of coding:

1. *No References to Science:* For example, no response, or "I don't know," or "can't remember."
2. *Descriptions of other school events or activities not related to science or vague descriptions.* For example, "I am doing some easy stuff ... learning money and minus and plus."
3. *References to Science:* These include descriptions of science vocabulary, content, activities, or processes. Examples are: "Rain, sun, and clouds," "About snacks that are good or bad," "Being healthy," "I learned about butterflies. Instead of chrysalis, people sometimes call it a cocoon," "I learned about the magnifying glass ... when you put it real close you see it big," "Living things, caterpillar[s]. They get into an egg—a little toy egg [and] when it cracks open it gets into a butterfly," and " Science is when you investigate."

Next, we reviewed all children's references to science further, to identify specific science-related themes. We identified two broad themes: *science content* and *science-related process activities*. We then sub-divided each into different content topics and different process activities. These reflected what the children had either engaged with during SLP activities or had learned (formally or informally) in other contexts, including school. The family of codes and sub-codes, with examples of children's responses, is shown in Table 6. In several cases, when children's responses addressed a number of themes concurrently, we assigned multiple codes to indicate the presence of all themes.

Coder Reliability

We (the first and third authors) established inter-coder reliability for children's references to science versus no references to science with the pilot year data; the reliability was 98.7%. The first author then coded all transcripts in the current data set for references versus no references to science.

We next focused only on those responses that referred to science. The first and third authors together coded 10% of responses, to develop a shared understanding of the categories and the coding process. This involved discussing the codes and transcripts extensively, identifying exemplars for each code, and iteratively clarifying the coding scheme as necessary. Once we were familiar with using the codes, we coded a new sample of 40 responses independently. The sample was comprised of 10 responses, selected randomly, from each of the four sets of data (SLP September, SLP December, SLP March, COMP March). The 40 responses were sequenced randomly and were without their ID numbers, so the coders could not identify the context or time

TABLE 6
Interview Codes and Examples

Category	*Guiding Examples*
1. No references to science	
a. Don't know or no response	*(We learn) lots of things. . .* or *I don't know*.
b. School activities or events <u>not</u> related to science, or too vague to classify as science-related	*Sometimes we paper cut things with scissors and glue them together. We draw things and color things. And that's the only three things*. (What do you learn?) *Like, I think we have to do something and do what the teachers and . . . and on the paper we have to write*.
2. Science-related references	
a. Science content and process	
i. Science content	
1. Living Things	*We learned about butterflies. When they come out their wings are wet, so they have to flap them so their wings will dry*.
2. Force and Motion	*How do cars go faster or slower. And we talked about going down the slide. Joshua would go slower than the teacher because she is bigger. How gravity is all around and it pulls us down*.
3. Marine Life	*I learn about our fish we have in here. They have bones inside of them*.
4. Dissolving, making solutions, mixing potions or creating formulas to change things or states	*How to make different colored science. So you use red and blue to make a purple color*. *Stuff that is scientific. It has different formulas- can change different things, like your voice or your body. Science is when stuff turns into anything*. *Some stuff that you make, potions that make you different. We don't do that at school*.
5. Other (technology, robots, weather, health, science-related professions)	*Rainbows! How to be a doctor!*
b. Science process activities	
1. Making predictions	*We predict. . .* or *We look and guess what is going to happen*.
2. Conducting investigations and experiments, figuring things out	*You investigate and learn about stuff. I look at it. I investigate frogs and bugs and bees and flies*. *We do water and sugar experiments*. *We try to figure out which one dissolves. We put some water in a cup and we put some salt in and we stirred it. And it dissolved. And we had some beans. And it didn't dissolve*.
3. Using science tools	(What do you learn?) *A lot of cool things. Measuring things, and water. Using a telescope, using trains to slide down ramps, using a microscope*.
4. Recording observations or findings	*I have a science notebook, about butterflies and also about how caterpillars turn into a cocoon after it's been there for so long it makes a cocoon, then poof- it becomes a butterfly*. (I am) *writing in my notebook*.
5. Reading science-related books	*We read books about fish*. *We learned a caterpillar book. The caterpillar was in a tiny egg book. Then it hatched. It was eat up and eating and eating. Then it got big. It went into a cocoon. And then it hatched out like a butterfly. It was black and orange with orange antennas*!
6. Share information and discuss with others	*We just talk about things. Things we don't know. Things, math, animals, fish, they breathe underwater*.

TABLE 7
Numbers of SLP Children who Referred to Science Versus Other Content Across the School Year

	Time Period					
	September		*December*		*March*	
Category	*n*	%	*n*	%	*n*	%
1. No references to science						
a. Don't Know or No Response	66	53.7	21	17.1	2	1.6
b. School Activities or Events not Related to Science	33	26.8	21	17.1	12	9.8
2. Science-related references (Content and/or process)	24	19.5	81	65.9	109	88.6
Total	123	100.0	123	100.0	123	100.0

of the year at which the data were collected. We then met, calculated agreement, and resolved inconsistencies through discussion, referring back to the category definitions, which we clarified if necessary. Agreement was 90% for science content, and 85% for science process activities. These percentages reflect both errors of omission (e.g., noting reference to 2 instead of 3 science themes) and commission (raters coding a statement differently). After establishing inter-rater agreement the remaining responses were coded by the first author.

Trends Within the SLP Group Across the Year

Analyses. In this section we present the analysis of SLP children's narratives. First, we examined whether or not children's narratives included science-related content and tested for trends over time using Cochran's Q statistic (Marascuilo & McSweeney, 1977). Second, we focused on all the science-related narratives and described patterns obtained at baseline, before participation in the SLP activities, and during the SLP activities (December and March). We conducted analyses to examine changes in the narrative patterns within these two periods using procedures for evaluating differences in dependent categorical data (i.e., Bowker's test for correlated proportions and the Stuart-Maxwell test of marginal homogeneity; Marascuilo & McSweeny, 1977; Marascuilo & Serlin, 1988; Sheskin, 2007). For each analysis we also examined differences between SLP classrooms and found no statistically significant effects. Therefore, the results reported here are for the entire group of SLP children over time.

Science Versus Non-Science Themes. Table 7 summarizes trends within the SLP group over time with respect to the number of children whose narratives contained descriptions of science versus children whose narratives did not include science. In September, prior to the SLP activities, a large number of the children did not make any references to science. Many (n = 66, 53.7%) stated that they did not know what they would learn in science. Others (n = 33, 26.8%) named what they thought they would learn about science in kindergarten but referred only to activities that could not be classified as science-related. In these narratives, children talked about literacy activities, classroom behaviors or expectations, other kindergarten routines, or a combination of these. Examples include:

"Playing and learning my numbers, doing sentences, and going outside too."

"How to read, stay in lines when you draw."

"You'll learn about reading and learning and Jesus."

"Reading books, learning, and practice dance and doing homework."

"To study and be nice to other people."

"How to listen and spell."

At the start of the school year, only 24 (19.5%) SLP children shared ideas about what science involved (e.g., "learn how to build a volcano," "caterpillars," "the rainforest"). However by December, 81 (65.9%) of the children made clear references to science themes, activities, and/or processes. Twenty-one children gave no response, and another 21 children confused science with other school activities, expected behaviors, or content. Examples of the latter responses include:

> "I learned about centers, play with play dough, blocks in the play house, legos, and paint. (What do you learn in science?) A lot of things. (Like what kinds of things?) I know how to spell . . . read (What kinds of science things?) I don't know, you have to draw things and go out sometimes."

The trend for more children to talk about science-related themes increased in the spring, with 109 (88.6%) children making references to science. Changes in SLP students' narratives over time were examined via Cochran's Q test. We tested for differences in the proportions of students who: (a) made references to science knowledge and activities; or (b) did not make references to science (Table 7). The results were statistically significant ($Q = 112.58$; $df = 2$, $p < .001$) indicating that engagement with science was related to the production of relevant ideas about the content and/or process of science. This conclusion was further supported by three post-hoc pair-wise contrasts conducted to test for differences between: (a) Time 1 (Sept.) versus Time 2 (Dec.); (b) Time 1 versus Time 3 (March); and (c) Time 2 versus Time 3. All three contrasts were statistically significant ($z_{T1\text{-}T2} = -5.11$, $p < .01$; $z_{T1\text{-}T3} = -7.67$, $p < .01$; and $z_{T2\text{-}T3} = -2.56$, $p < .01$) and confirmed an increasing trend in the production of relevant references to science over time.

Science Content Themes and Process Activities at Baseline. At the beginning of school, 13 out of the 24 children who referenced science-related themes thought that in science they would learn about living organisms such as different plants and animals (e.g., "butterflies and all that stuff," or "learn to teach my cousin what things do, how they live, and what they eat"). The remaining children's responses covered a wide variety of topics that included learning about the weather, electronics, mechanics, planets, and gravity, as well as about making or fixing things.

Most of the children ($n = 15$ out of 24) used a single term to describe what they thought they might learn in kindergarten science (e.g., "caterpillars," "plants, "the rainforest," "the weather," "robots," "light bulbs"). Five responses were about learning "how to" themes (e.g., "learn how to build a volcano," "learn how to grow hair," ". . . to fix daddy's car," " to mix stuff and if I mix them all together they will come out purple"). Finally, four responses included several general themes (e.g., "space, aliens, and animals," "doctors, spacemen, firemen," or "[how] animals grow, baby birds"). Children did not make any comments that reflected an understanding about the processes of doing science.

Science Content Themes and Process Activities Over Time. Past the September baseline, children's narratives reflected content and process activities from different themes covered in the SLP inquiry and literacy activities. Most children either talked about science content or about both process and content. Few children referenced science process activities without including the context within which the process activities were enacted. Specifically, at the mid-year assessment (December), 37 children referenced content, 34 referenced both content and process, and 10 referenced only process. At the spring assessment (March), 53 children referenced content, 54 referenced process and content, and 2 referenced only process activities. The few process-only references were typically short (e.g., "We make experiments kinda like other scientists do"; "We write and do experiments"; "We have science notebooks"; "We look through a magnifying glass"). The patterns for responses that referenced content-only or both content-and-process were comparable, with approximately equal numbers of children referencing content-only or both content-and-process within each time period. At the same time, as shown earlier in the analysis of science versus non-science themes, the number of science-relevant references increased significantly between these two time periods.

In Table 8, we provide characteristic examples of children's responses to support the validity of the coding scheme. Although this table shows the coding for a single content or process reference, it can be seen from several narratives that children sometimes made more than one reference to content and/or process. In these situations, additional codes were assigned to represent each child's statements as accurately as possible. For example, in Pat's narrative, shown below, separate codes were assigned to indicate references to content (living things) and process (using measurement tools, recording in the science notebook). Sample pages from Pat's notebook, illustrating his recordings about living things (living things I saw during the nature walk, mothers and babies, and habitats), are shown in Figure 7. The child's references to being careful were not coded, because no other child made a similar statement.

> We do good things in science. We don't spill the water. (What do you do in science?) We do science right now. We measure things and look at things, and touch them. And don't break it. You be careful. You do science and your best. You can write anything. (And then what happens?) Ms. Glaser (the SLP assistant) helps us write in our notebooks. We write about animals. Like fishes and tigers and elephants. You talk about snakes and birds. And a dog. And a cat. And a duck. (Pat, Spring Assessment)

Similarly, separate codes were given to Hineko's end-of-year narrative to account for references to content (marine life, motion) as well as to science process (science tools, reading science books, figuring things out). Sample pages from Hineko's notebook associated with elements noted in the narrative are shown in Figure 8.

> (What do you do in science?) Well, we see what's in our fish tank. We saw snails, anemone, rocks, and the temperature thing, I think it's called a thermometer. (What happens in science?) You learn

TABLE 8
Examples of SLP Narratives Referencing Science Content and Process Activities

Category	*Child[1] (Teacher)*	*Time*	*Narrative[2]*
Science Content			
Living Things	Valeria (Ms. Donnely)	December	***Learn about living things.*** (What else do you learn?) ***That living things need food and water***.
	Robert (Ms. Barr)	March	(What do you do in science?) *Learn*. (Learn what?) ***About living things and hibernating and stuff like that***.
Force & Motion	Rigo (Ms. Cannon)	December	***That there are trains on the bumpy slide and the smooth slide and the trains on the smooth side go faster.*** (The bumpy side) ***it goes slower because it has a lot of bumpies***. (Anything else?) *That a flower, it can drink water because it's alive, you know. In the soil, you know? It's down in the mud, but it can drink from there*.
	Drake (Ms. Barr)	March	(What do you learn?) *Science experiments.* ***One of them, we had bumpy ramp and a smooth ramp where two trains went down and we wanted to see which one went faster***. ***Smooth was faster***. (Anything else?) *We have notebooks that we color fish that are in our tanks*.
Marine Life	George (Ms. Tarkington)	March	(What happens in science?) *It means you're having fun.* ***We have a fish aquarium. It has snails and fishes in it. A yellow-tailed fish and a Nemo. And we learned about shells. About what they do. They don't move but if a crab or a snail is in it, then it moves***.
	Katie (Ms. Burke)	March	*Sometimes we learn science.* ***We learn about the fishes, where they live in. We learn about where fish breathe. How they breathe through gills. There were 2 Dorie fish. They had clown fish***.
Dissolving, Making Solutions	Kami (Ms. Barr)	December	***That things dissolve. We tried dissolving beans but it didn't work.*** (Anything else?) ***Well, salt dissolved.***
	Bob (Ms. Tarkington)	March	***Salt dissolves in the water but beans do not.*** (What happens in science?) *We got, use that thing that show what's really small* (the microscope).
Other	Kaleb (Ms. Donnely)	December	***We do scientist stuff. We learn how to build stuff. We talked about how you don't touch other people's food. We learn about germs.***
	Jamie (Ms. Donnely)	March	***We learn weather. Snowy, rainy, windy***.
Science Process Activities			
Making Predictions	Karen (Ms. Tarkington)	December	***We learn to make predictions. We made a prediction that the water would turn purple. I guessed right.*** *I learn about fun things*!
	Dora (Ms. Cannon)	March	***We learn how to predict and be a scientist. We predict what's going to happen, and if it happens, our prediction is right.***

(Continued on next page)

TABLE 8
Examples of SLP Narratives Referencing Science Content and Process Activities *(Continued)*

Category	*Child[1] (Teacher)*	*Time*	*Narrative[2]*
Conducting Observations, Investigations & Experiments	Peter (Ms. Cannon)	December	***Making experiments. We put the flower in green water and then we wait until the next day and it's red, oh wait, green, I mean, and the one in the clear water is the same. And you drink, the kool-aid dissolves. The powder does.*** (Anything else?) *That's all I remember. Oh wait, we rolled the trains down a bumpy and smooth ramp. And we had a smooth and bumpy ball, and the bumpy ball, it rolled down first.*
	Alysa (Ms. Cannon)	March	***We got to see experiments, to see if beans disappear in water. It didn't because it's big. The salt did because it's small. And if you put kool-aid in the water it dissolves.***
Using Science Tools	Mark (Ms. Barr)	December	*What's hot and how hot it is today*. (How do you know that?) ***You use a dodometer*** (sic, i.e., a thermometer). ***What weighs more on a scale. How tall you is. You use a ruler. We used a weather thermometer, and see how much it weighs***.
	Antonio (Ms. Donnely)	March	*I do hard work. I learn about science stuff, like anything science*. (What happens in science?) ***Your brain works, you write stuff so you don't forget. Your brain gets smarter 'cause you're learning about stuff. You can be like scientist and you use science tools.***
Recording in Notebooks, Reading Books, Talking about Science	Carla (Ms. Cannon)	December	***We use books, science books***. *I learn about living things and about little things*. (What kinds of little things?) *Germs are everywhere*.
	Tyree (Ms. Burke)	March	*We learn about fish and that's all right now*. (What do you do in science?) ***We read, draw pictures, write stuff in our journals, and we gather on the carpet and talk about it and write it up on the board, and read stories about fish.***

Note. [1]Children's names are pseudonyms
[2]Bolded quotes are directly associated with the coding category within which they are presented in the table. Some narratives were assigned multiple codes to capture all the themes noted. However, they are shown here as examples of one of the themes represented in the coding.

> all kinds of things. You learn more about things. Read science books and learn more. You can figure things out, like what goes faster and slower and see if something can go higher than another one.

Additional examples are shown in Table 8. Rigo's narrative (December, Force & Motion) was given an additional code for his reference to living things. Similarly, Drake's (March) statement was also coded for its marine life content, and references to process (using his science notebook to record information about the marine animals in the saltwater aquarium).

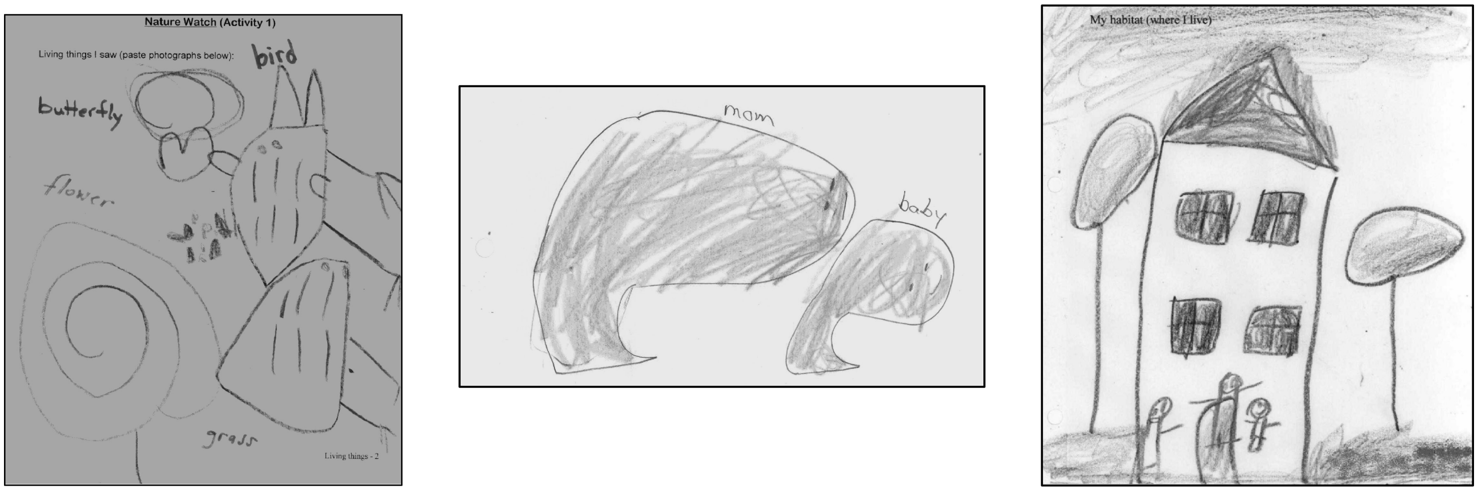
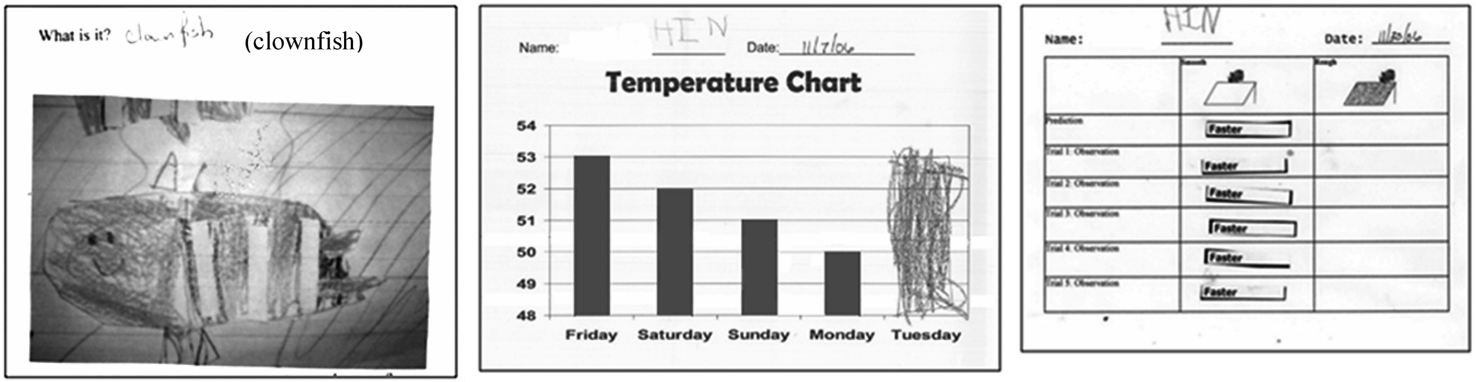


FIGURE 7 Pat's science notebook pages illustrating his inscriptions about living things and dictations to the teacher.



Marine Life: Description of a Living Thing in the Classroom's Aquarium

Tools: Recording Temperature

Motion: Making Predictions about Friction

FIGURE 8 Sample notebook pages illustrating Hineko's work in the Marine Life, Tools, and Force and Motion units.

TABLE 9
Number of Comments About Science Content and Process Activities in Children's Narratives

Science Content/Process Activities	*December* *n*	*March* *n*
Science Content		
Living Things	23	26
Force and Motion	45	10
Marine Life	1	71
Dissolving	12	10
Other	11	9
Science Process		
Making Predictions	4	3
Conducting Investigations and Experiments, Figuring Things Out	30	20
Using Science Tools	7	12
Recording Observations or Findings	3	21
Reading Science-Related Books	2	19
Sharing Results or Discussing with Others	3	13
Total	141	214

We computed the total number of references to content and process resulting from the coding process within each time period; these findings are reported in Table 9. In December, children with science-relevant references ($n = 81$) made a total of 141 statements that mentioned science process and/or content activities. In the spring, at the end of the fifth unit, the 109 children with science-relevant narratives produced a total of 214 statements about science content and/or process.

It is worth noting that children's content-related narratives (Table 9) were reflective of the information children had covered in SLP. For example, in December there were 45 (31.9%) content references to force and motion, whereas in March there were 71 (33.2%) content references to marine life. These two units were the last ones completed before the mid-year and spring assessments, respectively. However, even though more references were made to the most recently completed units, there were still many references to content and activities that the children remembered as a result of their engagement in earlier SLP units.

The frequencies shown in Table 9 provide, within each time period, an overview of the total references to content separately from the references to process activities. However, some children addressed more than one science content category or talked about process activities while referencing the instructional content for that activity. To examine changes between the two SLP periods, we computed the total number of content and process references made within each time period. Even though some children made more than two references, we decided to classify responses across three categories to avoid the problem of empty cells and/or cells with low counts. Results are shown in Table 10.

We used Bowker's test for correlated proportions (Marascuilo & McSweeny, 1977; Sheskin, 2007) to examine differences in the joint probability distributions of children's narratives over time. The test statistic was significant ($\chi^2 = 21.08$, $df = 3, p < .01$) and supported the conclusion that there were significant differences in the way the data were distributed about the main diagonal of Table 10. To explore the nature of the differences, we conducted three post hoc contrasts examining changes within sets of 2×2 cells of Table 10. These involved the following categories

TABLE 10
Total Number of References to Science Process and Content at the Mid-Year (December) and Spring (March) Assessment Periods

		Spring (March)			
	n of References	*0*	*1*	*2 or more*	*Total*
Mid-Year (December)	0	7	22	13	42
	1	3	13	21	37
	2 or more	4	13	27	44
	Total	14	48	61	123

(at both time periods): (a) 0–1; (b) 0–2; (3) 1–2. The first two contrasts were statistically significant, indicating that in the spring (compared to the mid-year assessment), there was a significantly higher proportion of children with one reference ($\chi^2 = 13.37$, $df = 1$, $p < .01$) as well as two or more ($\chi^2 = 4.76$, $df = 1$, $p < .05$) references to science. The third contrast was not statistically significant.

Three additional contrasts between pairs of the marginal probabilities (involving the total frequencies for each category in December and March) of Table 10 were examined using the Stuart-Maxwell statistic (Marascuilo & Serlin, 1988). Results confirmed that in March (compared to December), children had significantly: (a) fewer non-science-related responses, $z_0 = -.4.69$, $p < .01$; and (b) more responses in the "2 or more" category, $z_2 = 2.39$, $p < .05$. The contrast for differences in the 1-theme category (between December and March) was not significant.

Although the purpose of the present study was to document children's socially derived meanings about what science involves, rather than their understandings of specific science concepts, we did, on a post-hoc basis, note that in one third of the narratives (both in the mid-year and spring assessments) children spontaneously communicated their understandings about the specific concepts/information that they were sharing with us. For example, Carla (Ms. Cannon's class) spontaneously explained her understanding of the purpose of the carnation investigation associated with the Living Things unit (see also section on inquiry activities for a description of this activity): "We do experiments. We put the colors in the water and when it changed color, we put the flower in to see if it changed colors." Similarly, Anatoli (Ms. Burke's class) communicated his understanding of predator–prey relationships, a concept addressed in the Living Things and Marine Life units:

> I learn that fish have gills and they hide and food eaters hide to catch prey sometimes. It's funny when food eaters prey. Prey comes to it instead of hiding. Like fish who hide and get eaten. That's scary.

Additional examples of spontaneous explanations, shown in Table 8, include: (a) Rigo's explanation that the train on the bumpy side went "slower because it has a lot of bumpies" (Science Content, Force & Motion); (b) Drake's understanding of the purpose of the investigation conducted in the Force and Motion unit: "We wanted to see which one went faster" (Science Content, Force & Motion); and (c) Dora's procedural understanding that a prediction involves making a guess about an outcome, followed-up by observations to determine whether the outcome was consistent with the prediction (Science Process, Making Predictions).

Differences in SLP and COMP Children's Reports

Analysis of Science Narratives. This analysis examined differences between the SLP and COMP children in the spring of the school year (March). However, prior to conducting this analysis we examined differences within the COMP classrooms. The findings confirmed that there were no differences between the COMP classrooms on any of the variables.

Of the 70 COMP children, 58 (82.9%) stated that they did not have science in their school. When asked whether they knew about science, 27 children responded affirmatively and described their understandings. Of these children, 19 had science-relevant responses. The remaining children talked about other, non-science activities. For example:

> (What do you do in science?) Letters, numbers, the number line. (What happens in science?) How many shapes or sizes. (And then what happens?) Um. . . We don't have science.

Two children referenced enjoyment or fun, and one of those also mentioned the difficulty involved in learning science. They said:

> (If you had science what would you learn?) That it's fun. (Anything else?) That I like science. I don't know what we would learn.
> (What would you learn?) It would be hard work. Fun activities, homework, that kind of things (sic).

Of the 12 children who said that they did have science at school, only 5 described science-related activities. The remaining 7 children volunteered responses that referenced other school activities or behaviors not related to science. For example:

> (What do you learn in science?). Be quiet. Behave. That's very important. (What happens when you have science?) Be quiet. Centers. Play, and sometimes you get to work on [the] 'puter (i.e., computer).

One child talked about skill improvement that might result from science instruction:

> (What happens in science?) You get teached. (And what do you learn?) You get more better at it, at the science.

Thus, a total of 24 (34.3%) children made references to science, after stating that they: (a) did not have science at school but that they knew about science from other sources (e.g., an older sibling) ($n = 19$); or (b) they had science at school ($n = 5$). We conducted a χ^2 analysis to examine whether, in March, the proportion of SLP children with science-related responses differed significantly from those of their COMP peers. A significantly greater proportion of SLP (88.6%) than COMP (34.3%) students referred to science-relevant content and activities in response to the interview prompts, $\chi^2 = 61.47$, $df = 1$; $p < .001$.

A total of 27 science themes were mentioned by the 24 children in the COMP group. Examples across the coding categories are shown in Table 11. There were a total of 12 references to science as the enterprise of making solutions; interestingly, 11 of these references portrayed science as involving the use of magical potions or dangerous chemical solutions. This is in sharp contrast to the small number of references about dissolving and making solutions identified by the SLP

TABLE 11
Children's Science Narratives: Comparison Group

Category	*N*[1]	*Example*
Science Content		
Living Things	4	(What happens in science?) *We color. We write our names. We write stuff*. (What do you do in science?) ***Bugs***. *We just color them in, that's all*. (What do you learn?) *About books*. (What kinds of books?) *"Sam I am." That's all*.
Marine Life	2	(What do you learn?) *Learning to make stuff*. (Like what?) ***Dolphins, whales, the boat, alligators, sharks***. (What do you do in science?) *We kind of make them with paper and we paint them. We sing the alphabet. We do math*.
Dissolving, Making Solutions	12	***Science is like when you have potions and stuff and they turn into different things.*** (Do you learn this in school?) *Actually, my brother teached me how to do science. So I know it in school. He's 8*. (What happens when you do science?) *Like making a box! You learn how to make paper. When we get done, we eat snack. And if you do everything right you get a sticker or candy. I got that*. (What else do you do?) ***I made blue and green, we made colors in our class and then we mixed play dough and made different colors.***
		If you go to science you have to be big. You have to be big to do science. If you're little, you'd get hurt. (What else would you do?) ***Do stuff with chemicals, like mix them up together and they'd blow up.***
		(What happens when kids have science in school?) *They can make stuff*. (Like what sort of stuff?) ***Like people who are frozen, or make little people, or make little monsters. Or they can make little bubble gum or rocks.*** *My brother Diego goes on the bus to do science. He is 12. That's all I know*.
Other	5	*You make stuff*. (Like what stuff?) *Electric stuff, like electric robots*. (Anything else that science is about?) *Um, that's all I know*. (What happens in science?) ***Um, how to make a robot and computers.*** (Anything else?) ***Um, you can make doggie robots.*** *That's all I know*.
		Science is learning about stuff, like being a Doctor when you grow up, or how to be a science teacher. The science teacher teaches you how to be a science person.
Science Process Activities		
Conducting Investigations & Experiments	3	(If you had science in your school what would you do?) ***Make experiments.*** (What sort of experiments?) *I forgot*. (What else would you do if you had science?) *Make a rabbit*. (How?) *Bring a potion and do it*.
Other	1	(If you had science, what do you think you'd be doing?) *I do it at home*. (And what happens when you do science?) ***We read books in science. You choose one from the book fair.*** (What are the science books about?) *I don't know, about Clifford. Because my brother took my book that tells me how to do my science*. ***He has, he gots 10 of them science kits. My brother gets the volcano and I don't get it sometimes.*** *He's 7. I want to get the volcano*!

Note. [1]N refers to the number of narratives in each category. The total does not add up to 24 because there were 3 children with two references to science, bringing the total number of science narratives to 27.

children in both December (8.5%) and March (4.7%). SLP children described dissolving in the context of activities associated with making predictions and testing them (i.e., Table 1: What is Science? unit) or with an investigation designed to generate discussion about internal movement in plants (i.e., Table 1: Living Things unit). References to science as involving magical potions were not made by any child in the SLP group. Also, we noted that over one-half of the 24 COMP children with science narratives noted that science is appropriate for older students or adults but not necessarily for kindergarteners. For example:

> We're too young! Kindergarteners are too young for science. My brother does science. He likes science, and he is good at science. (How old is your brother?) 12! (What do you think you can learn in science?) How to make gross stuff. (What sort of gross stuff?) Like disgusting foods, like Dr. Dreadful!

One child who did not give a science-relevant description said that he did not know about science because in kindergarten they are expected to work on reading: "ABCs, numbers, read, and read little books and we make sure we go to school. Because if you are in 3rd grade you can learn science and math." Comparable references to science as an enterprise that's not appropriate for young children were not made by the SLP children.

It is noteworthy that some children's comments were consistent with our observations of COMP classroom activities noted in the Method section (Comparison Classroom Activities). Specifically, on the basis of the classroom discourse and choice of activities, we deduced that COMP children may have simply perceived the science lessons as art activities. Examples supporting this inference are shown in Table 11: "Bugs, we just color them" (Science Content, Living Things); or "Dolphins, whales, . . ., sharks. We kind of make them with paper and we paint them" (Science Content, Marine Life). These contrast sharply to SLP children's content-specific references (e.g., "that living things need water," or "we learn about where fish breathe. How they breathe through gills").

What Do You Learn in Kindergarten?

To provide additional information on children's views about their learning experiences in kindergarten, we administered the What do you Learn in Kindergarten (WILK) measure to the 123 SLP and 70 COMP children in the spring (March). As with the previous analyses, we found no classroom differences within the SLP condition. Also, the COMP classrooms did not differ on this measure. However, there were statistically significant differences when we compared the SLP and COMP groups, using a one-way MANOVA with the Reading-Math and the Science subscales of the WILK as the dependent variables. Following a significant multivariate statistic, $F\ (2, 187) = 115.65, p < .001$, we conducted a post-hoc univariate analysis to examine differences within each WILK subscale. There were no statistically significant effects on the Reading-Math subscale of the WILK. SLP ($M = .90$, $SD = .18$) and COMP ($M = .87$, $SD = .18$) children's response to items about typical kindergarten content (reading and math) were comparable. However, there was a significant difference, favoring the SLP children, on the Science subscale of the WILK, $F\ (1,188) = 177.61$, $p < .001$. SLP children ($M = .83$, $SD = .20$) endorsed significantly more science content and activity items than the COMP group ($M = .35$, $SD = .29$).

DISCUSSION

In this study we examined children's emerging social meanings about science during the first year of school by considering their narrative responses to: (a) initial questions asking whether or not they expect to learn science in kindergarten and (b) follow-up open-ended prompts about "what happens" in science. Our research contributes to the growing literature on young children's early science learning in several important ways. First, we add to the knowledge base on young children's ideas about science at the beginning of school and document trends in the evolution of these ideas over time. We provide evidence that, when given opportunities for participation in integrated science inquiry and literacy activities, young children begin to develop views of science as a distinct academic domain that comprises its own disciplinary content, language, and processes. Second, we confirm that in constructing notions about what counts as science, children draw on experiences in their familiar worlds, including those provided at school, in their family, and/or other out-of-school contexts. The data highlight the important role of the instructional context in shaping children's emerging social meanings about science. Without opportunities for explicit, conceptually coherent, and sustained science instruction, children's ideas about science and who-is-doing-what in science are limited both with respect to the content and the epistemic processes of the discipline.

Our findings represent children's constructions of the social meanings they came to attribute to science; however, they do not detail children's understandings of specific science concepts and epistemic processes. Moreover, although children's interpretations are based on their experiences with science in school and/or other contexts, they may not necessarily reflect accurately the actual events that gave rise to these experiences. At the same time, children's storied descriptions are not independent of these events; they are situated around them and are, as a result, a valuable resource: "The storied descriptions people give about the meaning they attribute to life events is . . . the best evidence available to researchers about the realm of people's experience" (Polkinghorne, 2007, p. 479).

The Role of Context in Children's Evolving Views About Science. Our hypothesis that young children are unlikely to come to school with structured meanings about science was supported. We found that in the first month of kindergarten, fewer than 20% of the children offered relevant descriptions about what they might learn in kindergarten science. This was expected, in light of the dominant role of literacy in the early years and the widely held belief in the primacy of fictional narrative for engaging children in reading (Duke, 2000). In addition, considering that science encompasses many different sub-disciplines, it may be that science-related content or activities are not identified as "science," but labeled by each specific topic (e.g., "plants," "sinking and floating").

Of the few early narratives (pre-SLP) with science-relevant elements, the majority referenced content across a number of topics (animals, plants, environment, weather, light bulbs). Most of the children who came to school with understandings about science believed that learning science would involve the acquisition of more knowledge across topics that they thought pertained to science. It is interesting that approximately 20% of the science-relevant narratives reflected that learning about science would involve learning about how to fix things or how to create different things. This parallels what Tucker-Raymond et al. (2007) identified as an engineering stance, a view shared by 27% of 1st–3rd graders prior to the start of the ISLE program of integrated inquiry and literacy activities. Children holding this stance characterized science as the enterprise of "making things." However in the post-interview, after children had engaged in the science activities, they had moved away from that stance to other stances nurtured by the ISLE science program (e.g., conducting experiments, finding things out). This represents a second parallel to our present investigation.

Children's narratives from interviews at the mid-point and end of the SLP sequence reflected primarily the content of the SLP activities. Also, continued engagement with science inquiry and literacy was associated with increases in children's relevant descriptions about science. At the mid-point of the intervention (after eight weeks of SLP activities) there was a significant increase in the number of children who readily referenced different aspects of science content and/or processes. By the end of fifteen weeks, 89% of the children had appropriated the science language used in their classrooms.

A major goal of the SLP activities is to engage the children in explicit science discourse. As shown in a study of Year 1 SLP activities (Samarapungavan et al., 2008), as well as in the excerpts associated with the Year 2 activities presented in the current study, teachers model specific science vocabulary and scaffold children's participation in discourse around science concepts. SLP children are socialized to use appropriate science language throughout the inquiry and reading activities: During discussions of science content, in the process of using science tools to observe and measure, through the use of inscriptional tools (e.g., notebooks and idea boards) to record predictions, observations, and findings, and in post-inquiry discussions and activities. In the present study, we document that children's interpretations of their science experiences reflected a range of topics and language learned during the SLP activities. Through their narratives, the children shared with us ideas about the content of science and the epistemic processes that are integral to the conduct of science (e.g., asking questions, conducting observations, acquiring knowledge through reading relevant texts, conducting experiments, drawing conclusions, sharing their findings). Considering that narratives are discourse about one's self-knowledge and sense of identity (Brown & Spang, 2007; Gee, 2005), the SLP children's accounts of their science experiences also revealed aspects of children's views of themselves as participants in the process of science. These early constructions, though far from being integrative and self-defining, are part of children's life stories and constitute material for the making of future identities (McAdams, 2001).

The key role of context in learning about science was further substantiated by our analysis of the comparison children's responses. At the end of the school year, the majority of children who received the regular kindergarten instruction reported that they did not learn science in kindergarten and that they did not know what science involved. We do know, however, from both our videotaped observations and the interviews with comparison teachers, that the children did participate in a number of different science activities. It is of note that these were not labeled "science." Moreover, they were taught as stand-alone topics without an explicit focus on science learning as a process of constructing, evaluating, and sharing knowledge. They did not involve explicit science discourse and though there was integration of the science content with literacy and art, there was little attention to disciplinary integrity. The blurring of boundaries across content domains in ways that disregard the objectives, norms, and linguistic conventions of individual disciplines is not likely to privilege children's meaningful constructions of each discipline. We argue that this is why the majority of COMP children did not express awareness that they learned science in kindergarten. The analysis of SLP and COMP children's responses on What I Learn in Kindergarten further confirmed that both groups of children noted a number of literacy (e.g., reading, learning about letters, learning about books) and numeracy activities (e.g., counting, learning about numbers and shapes) learned in kindergarten. In contrast, when asked about specific science content and vocabulary (e.g., making predictions, using a science notebook, learning about living things, learning about how things move) COMP children maintained that they did not learn about these in kindergarten.

During the interviews, some comparison children reported that they were familiar with science, but many appeared to hold naïve views about science as a dangerous or magical enterprise. Their conceptions of science appeared to be the result of learning through interactions with older siblings, or from experiences with store-bought science materials (e.g., volcano kits) or toys (e.g., Dr. Dreadful freaky food lab) that children played with at home. These children's narratives parallel the themes identified in children's stereotypical drawings of a scientist (e.g., male, wearing glasses and lab coat, having crazy hair, using laboratory equipment; Finson, 2002). For example, Barman (1999) found that 86% of the K–2nd graders depicted scientists as working in a lab. It is imperative, however, that children develop more inclusive and realistic notions of the realm of science than these stereotypes convey, particularly as a means to encouraging greater diversity in the scientist population.

In contrast to the SLP children, COMP children did not see themselves as part of a community of science learners. Of those who were familiar with science, some referred to their involvement and/or interest in science as individuals engaged in isolated activities at home (e.g., "I want to get the volcano [kitset]"). Others simply reported that science is not appropriate for young children, but is meant for others who are older and more knowledgeable.

It is important to reiterate that the data provided in this article are not offered as a direct assessment of children's science learning outcomes from the SLP project (learning outcomes are being explored in separate study). Rather, the data represent children's developing ideas about what it means for them to engage in science at school, and show how different contexts of science learning in the intervention and comparison classrooms are differentially associated with these ideas.

CONCLUSIONS, LIMITATIONS, AND IMPLICATIONS

The trends in the SLP children's responses, documented over time, suggest that sustained and meaningful participation in conceptually coherent science programs is crucial for children to develop schemas about science as well as of themselves as science learners. SLP children's narratives illustrate the different ways in which children engaged with science. Unlike their comparison peers, SLP children saw themselves as knowledgeable about those things that count as science and appropriated the discourse in their classroom contexts as they described their experiences with the content and epistemic processes of science.

Although our findings provide new information about young children's experiences with science, there are several limitations that warrant attention in future research. Specifically, the quasi-experimental nature of the design makes the SLP versus Comparison group differences suggestive, rather than conclusive. Despite our efforts to match the SLP and comparison schools on a range of achievement and social context characteristics, there is no guarantee that we obtained comparable samples of children and teachers. Also, comparisons between the SLP and COMP groups were conducted at the end of the school year, making it difficult to determine whether these groups had similar notions about science at the beginning of school.

Finally, because of the integrated nature of the inquiry and literacy activities, we cannot address questions about which specific aspects of the intervention made a stronger contribution to children's emerging ideas about science. Keeping in mind that both literacy and numeracy are integral parts of inquiry, this issue could be explored in future research. However, from a purely practical standpoint, the heavy focus on literacy in the early grades makes it unlikely that teachers will take on the implementation of inquiry activities unless they are convinced that science will not take away from their literacy program. Consistent with this view, it's been argued that "science curricula, highly suffused with language arts and mathematics may be science education's best bet for gaining a foothold for ambitious inquiry instruction in elementary schools" (Marx & Harris, 2006, p. 475). Our discussions with the SLP teachers did not produce any evidence that the SLP science lessons detracted from the literacy or math goals of the kindergarten curriculum. Further, our analysis of end-of-year achievement differences between the SLP and COMP groups, based on a standardized achievement measure of passage comprehension, showed that the SLP children performed significantly better than their regular classroom peers (Mantzicopoulos, Patrick, & Samarapungavan, 2009). However, these data are suggestive at this point. This is something that we plan to address in subsequent research along with an analysis of children's science learning in SLP and COMP classrooms.

Overall, our results strengthen the claim that science instruction should begin by the early school years if children are to develop, not only the requisite skills and knowledge for careers that involve science, but the view that engaging in science is a legitimate part of who they are and may become. However, it should also be acknowledged that interventions such as the SLP are probably not easy to implement without several sources of support (classroom assistance, materials, professional development).

Although our findings are encouraging, additional research is necessary to explore the relationships between children's social meanings about science with science learning and science achievement. Empirical evidence is also needed to support the assertion that early involvement with science is necessary to encourage and sustain children's continued interest and engagement in science, and to promote science-related achievement and educational and career choices.

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APPENDIX

Outline of Transcription Symbols

[	Overlapping utterances spoken by two or more people at the same time
//	Break in the transcript, move to a later section
. . .	short pause
. . . . . .	longer pause
CAPS	Emphasis
"CAPS"	Teacher reading from book
:::	short sound stretch
::: :::	longer sound stretch
!	Animation
?	Rising intonation
**	Softness
()	Transcription notes
. . . (m)	teachers' management comments (omitted from the transcript)