JOURNAL OF RESEARCH IN SCIENCE TEACHING VOL. 46, NO. 2, PP. 166–191 (2009)

# Motivation for Learning Science in Kindergarten: Is There a Gender Gap and Does Integrated Inquiry and Literacy Instruction Make a Difference

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*Received 29 July 2007; Accepted 14 July 2008*

Abstract: We investigated whether kindergarten girls' and boys' ($N = 162$) motivation for science (perceived competence and liking) differed. Children were ethnically and linguistically diverse, primarily from low-income families, and attended one of three schools. One school offered a typical kindergarten science experience. Kindergarteners in the other two schools participated in the Scientific Literacy Project (SLP)—a program based on a conceptually coherent sequence of integrated science inquiry and literacy activities. SLP lasted either 5 or 10 weeks. Regardless of sex, both groups of SLP children had greater motivation for science than children who had only the regular science experience. Moreover, children receiving 10 weeks of SLP reported greater science competence than those who received 5 weeks. Boys in regular classrooms reported liking science more than did girls, however there was no sex difference for SLP children. These results are supported by interview data accessing children's ideas about science. The findings suggest that early meaningful participation in science is likely to promote girls' and boys' motivation for science. © 2008 Wiley Periodicals, Inc. J Res Sci Teach 46: 166–191, 2009

**Keywords:** kindergarten; motivation; perceived competence; liking; sex/gender differences; inquiry; literacy

Females are under-represented in degrees earned and careers related to physical science, computer and information science, and engineering. Females also select non-compulsory science classes in high school less often, compared to males (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, 2000; U.S. Department of Education, 2004, 2006). This state of affairs is problematic for several reasons. Because they tend to not choose the necessary science courses, women have diminished access to a range of prestigious and high-paying careers, relative to men. Also, with an under-representation of women, there are too few workers with expertise in science, technology, and engineering to meet the needs of society. Furthermore, having limited diversity of workers shortchanges society of the breadth of potential perspectives and beneficial innovations (Baker, 1998; Eccles, 1997; Jacobs, 2005; Nichols, Gilmer, Thompson, & Davis, 1998).

Many scholars have argued that sex[1] differences in science-related occupational and educational choices cannot be accounted for by differences in ability or achievement (e.g., Bleeker & Jacobs, 2004; Catsambis, 1995; Spelke, 2005; see Brotman & Moore, in press, for a comprehensive review). Instead, these researchers suggest that explanations for the under-representation of women in science, technology, and engineering most likely lie in other factors, such as cultural expectations and differential opportunities for success. Such factors in turn influence women's motivation for science. Science is often viewed stereotypically as a domain that males prefer and are more competent at, compared to females (Andre, Whigham, Hendrickson, & Chambers, 1999; Baker, 1998; Campbell, 1991; Nichols et al., 1998). Central to

Contract grant sponsor: Institute of Education Sciences, U.S. Department of Education; Contract grant number: R305K050038.
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DOI 10.1002/tea.20276
Published online 31 December 2008 in Wiley InterScience (www.interscience.wiley.com).

achieving equity between the sexes, then, is that females perceive themselves to be as competent at science, and to enjoy science as much, as males do.

Because there are differences in males' and females' perceived competence, enjoyment, and selection of science classes at college and high school (e.g., American Association of University Women, 1999; U.S. Department of Education, 2004, 2006), researchers must consider students' perceptions about science in earlier grades. Sex differences in students' beliefs about their science competence have emerged by middle school (Beghetto, 2007; Jovanovic & King, 1998), and there is indication they are present in the elementary school years (Andre et al., 1999; Gardner, 1998; Licht, Stader, & Swenson, 1989). Unfortunately, there is a dearth of research that examines children's beliefs about science in the beginning school years. This information is vital, because attempts to promote gender equity early may help prevent or attenuate the future divergence along gendered patterns of engagement that is currently prevalent.

To address the need for research on the emergence of sex differences in young children's views about science, we investigated whether or not girls and boys in kindergarten differed in beliefs about their competence in, and liking of, science. We collected data in three schools serving ethnically and linguistically diverse students primarily from low-income families. One school offered a typical kindergarten experience learning science. In the other two schools kindergarteners participated in the Scientific Literacy Project (SLP; Mantzicopoulos, Patrick, & Samarapungavan, 2005)—a program that is based on a conceptually coherent sequence of integrated science inquiry and literacy activities in line with recommendations by the National Research Council (2000, 2001, 2007). We examined whether: (a) girls and boys differed in their perceived competence in and liking of science, (b) children who engaged in SLP for 5 or 10 weeks expressed different beliefs about their science competence and liking of science compared to those who had a regular kindergarten science experience, (c) the pattern of girls' and boys' motivational beliefs differed for those who participated in SLP inquiry and literacy activities and for those who did not, and (d) children's ideas about science differed depending on type of science instruction (SLP or regular).

## Motivational Beliefs About Science

Current theories of motivation for academics are based in social cognitive premises (Pintrich & Schunk, 2002). They are social in that they view learning as influenced by the social context, and cognitive in that they emphasize students' beliefs and perceptions about themselves, about the activity or subject, and about the context. Reflecting this foundation, in the current study we investigate children's motivation for science by examining reports of their beliefs or perceptions of themselves (i.e., their competence and liking), their beliefs about what science as a subject involves, and we consider the instructional context in which they are taught science.

We frame the current study within Eccles et al.'s (1983) expectancy-value theory that views individuals' motivation as influenced proximally by both their expectancy of success in a task or subject and by their valuing of the task or subject (Eccles et al., 1983; Eccles & Wigfield, 2002). These two beliefs are embedded within and influenced by an array of factors, including prior experiences, immediate contexts (e.g., family, school), and the larger cultural milieu (e.g., stereotypes, media). Expectancy beliefs involve perceptions of one's competence or ability and also confidence about future success (Eccles, Wigfield, & Schiefele, 1998). Students' current self-perceptions of competence are related positively to indicators of motivation (e.g., effort, persistence, choosing challenging tasks), to learning-related behaviors (e.g., problem-solving, use of cognitive, and self-regulatory learning strategies), achievement, and to future motivation (Eccles et al., 1998; Nieswandt, 2007; Wigfield & Eccles, 2002). Value involves beliefs about the interest, importance, and usefulness of tasks or subjects (Eccles & Wigfield), and is related positively to deep learning strategies, achievement, and to educational and occupational choices (Eccles et al., 1998; Jacobs, 2005; Wigfield & Eccles).

Competence and value beliefs are distinct from each other, and both vary intra-individually for different subjects (Marsh & Craven, 2006; Schunk & Pajares, 2005; Wigfield et al., 1997). Even the competence beliefs of children in kindergarten and first grade differ for different subjects, and the value they ascribe to activities also varies by domain (Eccles, Wigfield, Harold, & Blumenfeld, 1993; Valeski & Stipek, 2001). Young children also differentiate between their competence in, and their value or liking of, subjects, at least for reading, math, sports, and music (Chapman & Tunmer, 1995; Eccles et al., 1993).

Expectancy-value theory provides an important framework for understanding motivation and has been used extensively in research with older students to document science-related beliefs and explore pathways to individuals' choices, including career choices (e.g., Eccles, 2007; Jacobs, Finken, Griffin, & Wright, 1998; Jovanovic & King, 1998; Simpkins, Davis-Kean, & Eccles, 2006; Simpson & Oliver, 1990). It has also been used fruitfully with samples of young children to investigate motivational beliefs about reading and mathematics (e.g., Chapman & Tunmer, 1995; Eccles et al., 1993; Wigfield et al., 1997), although to date, not about science. More recently, it has guided the development of a measure of young children's beliefs about their competence in and value of learning science (Mantzicopoulos, Patrick, & Samarapungavan, in press). We use an expanded version of this measure in the current study to examine motivation-related sex differences about learning science.

## Perceived Competence in Science and Sex Differences

Individuals' beliefs that they are competent and can be successful are important for learning and achievement. When people are confident, they are most likely to put time and energy into learning, and persist rather than give up when experiencing difficulty (Eccles et al., 1998; Schunk & Pajares, 2005). Thus, perceptions of competence at science are strong predictors of future science achievement (Nieswandt, 2007; Simpson & Oliver, 1990; Welch, Walberg, & Fraser, 1986). Unfortunately, though, children typically express beliefs that science is more difficult than many other school subjects, and that they are better at language arts and math than at science (Andre et al., 1999; Cleaves, 2005; Licht et al., 1989; Watson, McEwen, & Dawson, 1994).

Many studies have identified that boys, on average, believe they are more competent or likely to be more successful at science than do girls during the middle grades (Anderman & Young, 1994; Beghetto, 2007; Jovanovic & King, 1998; Kahle, Parker, Rennie, & Riley, 1993; Licht et al., 1989; Meece & Jones, 1996; Simpson & Oliver, 1990) and high school (Campbell, 1991). Girls see themselves as having equal (Britner & Pajares, 2006) or lower (Anderman & Young, 1994; Deboer, 1986) competence but receive higher grades in science than do boys. Andre et al. (1999) asked children about their competence in both life science and physical science and found that, in kindergarten through sixth grades, boys reported greater competence perceptions than girls in physical science; there was no difference for life science. Although both sexes typically report declines in perceived science competence with increasing grade level, girls exhibit steeper decreases than boys do (Greenfield, 1997; Jovanovic & King, 1998). Girls report being less competent in science than in reading or math, but boys report no difference across those subjects (Licht et al., 1989).

There is surprisingly little research that has investigated sex differences in science competence perceptions with young children. Sex differences are present at the beginning of school for other domains of academic perceived competence, such as reading, language, and math, as well as for non-academic domains such as music and sports (Eccles et al., 1993; Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Marsh, Craven, & Debus, 1991, 1998; Wigfield et al., 1997). However, there is some indication, as noted previously, that girls and boys in the early elementary grades do hold different beliefs about their competence in science (Andre et al., 1999). In the present study we investigate whether or not girls' and boys' perceived science competence is similar in kindergarten. We build on previous research by focusing only on kindergarten, rather than an aggregate of many grade levels, given that children in kindergarten hold conceptions about science—what it is and how good they are at it (Mantzicopoulos et al., 2008). We also add to this research by using new scales to assess children's perceived competence in different aspects of science. We chose to ask about science in general, rather than differentiate between life and physical science, because we had no reason to think that the children would be familiar with these distinctions, given the typical sparse attention to science in kindergarten. Specifically, we asked about science content, such as knowledge about living things and marine animals that children would be familiar with as a result of their kindergarten experiences. In addition, our measure probed for children's beliefs related to their knowledge of the processes of doing science (e.g., making predictions, recording observations). By accessing a broader range of competence beliefs we move toward the goal of representing a comprehensive model of children's motivation for learning about science.

## Interest in and Liking Science and Sex Differences

Although competence beliefs are central to motivation, the value individuals hold for different domains also plays a crucial role. Value and competence beliefs are correlated positively, but have unique associations with various outcomes. Whereas perceived competence is most strongly related to achievement, value predicts decisions about which subjects students continue learning and which occupational paths they pursue (Wigfield & Eccles, 2002). Thus, even if students feel confident that they can do well at a subject, they are unlikely to continue with it if they find it uninteresting, unpleasant, or too costly in time or effort. This is the case for value beliefs about science (Lyons, 2006), and has been identified as one of the strongest reasons for the relatively small numbers of women working in science, technology, and engineering (Eccles, 1994, 2007; Jones, Howe, & Rua, 2000; Miller, Blessing, & Schwartz, 2006). There are different types of value, including liking or interest, importance, and usefulness, although young children do not distinguish between these in self-report measures (Wigfield & Eccles).

In general, children report less interest in science across the years between upper elementary and high school (George, 2006; Greenfield, 1997). Furthermore, children in kindergarten through sixth grade report liking science less than they do other subjects, and liking physical sciences less than life sciences (Andre et al., 1999).

Most studies that address sex differences in interest and liking of science have been conducted with students from the upper elementary grades onward. Results are mixed; some studies found that boys reported liking science more than girls did (Catsambis, 1995; Cousins, 2007; Harty, Samuel, & Beall, 1986; Miller et al., 2006; Oakes, 1990; Simpson & Oliver, 1990; van Langen, Rekers-Mombarg, & Dekkers, 2006), whereas others found no sex differences (Shepardson & Pizzini, 1994; Simpkins et al., 2006; Slate & Jones, 1998). Boys like physical sciences more than girls do, whereas girls like biological sciences more (Adamson, Foster, Roark, & Reed, 1998; Baram-Tsabari, Sethi, Bry, & Yarden, 2006; Dawson, 2000; Jones et al., 2000; Kahle et al., 1993; Watson et al., 1994). We extend the research on sex differences in science by investigating kindergarten boys' and girls' reports of liking science—a topic where research is critically needed.

## Motivation and Inquiry-Based Science in the Early Grades

Increasing the motivation of students to learn science is a significant objective of the National Science Education Standards (National Research Council, 1996, 2000, 2007). These standards emphasize inquiry-based instruction as integral to promoting motivation, as well as understanding. However, the overwhelming majority of inquiry-based science curricula have been developed for children in the upper elementary grades and beyond. Only a few programs have been developed for preschool and kindergarten children; these include *Head Start on Science* (Hammrich & Ragins, 2002; Klein, Hammrich, Bloom, & Ragins, 2000), *ScienceStart!* (Conezio & French, 2002; French, 2004), and *Preschool Pathways to Science* or PrePS© (Gelman & Brenneman, 2004). Limited evidence exists on these programs' instructional framework and outcomes. Although direct comparisons between SLP and other existing early science programs is beyond the scope of the current study, we note that our approach to inquiry science is compatible with that outlined by Gelman and Brenneman (2004). Our approach to literacy is based on dialogic reading strategies (e.g., Whitehurst et al., 1999) using informational text for children. Other programs also use reading experiences along with science activities (e.g., French, 2004), however, there is limited information on the types of books that are used, as well as the science-related reading program.

We outline the features of SLP in the method section (see also Samarapungavan, Mantzicopoulos, & Patrick, in press, for more detail). Research about the effects of early science inquiry programs is sparse, and outcome measures are limited to broad achievement data, such as tests of vocabulary (e.g., French) and pre-post-intervention gains in science knowledge (Klein et al., 2000). Information about sex effects within inquiry science in the early grades is also limited. Klein et al. report that first grade girls tend to score significantly lower than boys on both science content and application, but that they match or even surpass the boys following science instruction. However, questions about whether these programs are equally effective for boys' and girls' motivation remain unaddressed.

Thus, although inquiry-based instruction may make learning science significantly more interesting than the traditional teacher- and textbook-dominated instruction did, its introduction in the middle grades may attenuate motivational benefits. That is, with little to no experience with science inquiry, and scant attention to science at all, children in the early grades may develop negative beliefs about science that are hard to change even with inquiry-based instruction in later years.

Beginning inquiry-based science instruction in the early grades is sometimes suggested as a way to prevent the negative patterns whereby children tend to view science as more difficult and less enjoyable to learn than other subjects (Andre et al., 1999). This state of affairs is compounded by the fact that few children have substantive opportunities to engage in learning science in the early grades. Only 6–13% of instructional time is spent on teaching science in grades 1–4 (National Center for Educational Statistics, 1997; National Institute of Child Health and Human Development, 2005; Weiss, Pasley, Smith, Banilower, & Heck, 2003). Science is particularly sparse in the earliest grades, when there is an almost exclusive focus on literacy and numeracy (Lanahan, Prinicotta, & Enyeart, 2006), and it is not until much later in elementary school that significant instructional time is allocated to science.

Early academic experiences promote the development of children's self beliefs in different domains (Wigfield & Karpathian, 1991). For example, children's experiences while learning to read influence their enjoyment of reading, as well as their views of themselves as competent readers (Aunola, Lesinen, Onatsu-Arvilomni, & Nurmi, 2002; Chapman, Tunmer, & Pronchow, 2000). Similarly, positive early experiences with mathematics lead to children developing beliefs that they enjoy math and are competent at it (Helmke & van Aken, 1995). Following from that research, it may be that for young children, extended and meaningful opportunities to engage in science in the classroom promote both liking of science as well as perceptions of competence in the subject. And, given that inquiry-centered instruction is associated with more positive beliefs than other types of instruction (textbook or worksheet questions, and traditional lab activities) are (Shepardson & Pizzini, 1994), we sought to investigate whether young children who participated in SLP reported greater perceived competence in the content and process of science as well as liking of science compared to children who had a typical kindergarten science experience.

## Beliefs About What Science Involves

How students conceptualize the subjects they learn about is related closely to their beliefs about themselves as learners of that subject. With respect to the current study, children's beliefs about their competence for science and liking of it are linked inextricably to how they view science, all of which explain motivated behavior. In contrast to the quantitative approach we took to measuring perceived competence and liking, we used open-ended questions and qualitative analysis to identify children's beliefs about what science involves. This afforded us insights into the meanings they constructed as a result of their experiences.

High school students' views about science influence their decisions about elective courses and college majors. Many students do not continue with science because they see it as irrelevant to them and their lives (Lyons, 2006). Furthermore, males and females tend to give different reasons for their plans of whether to major in science or not (Miller et al., 2006). In response to being asked why males are more likely to be scientists than females, Miller et al. found that females gave answers such as "Guys are more physical, and in science they can blow things up," "Males are more likely to like messing with chemicals and explosives," and "More guys are interested in killing stuff and blowing countries up. Maybe women tend to be happier with grass than metal" (p. 374), whereas males did not. Thus, females' views of science as involving chemicals, explosions, and metal appear to influence their science motivation. Those findings parallel those of Jones et al. (2000), who reported that more sixth grade males than females "perceived science as involving power. . .destruction and danger, [and] creation of societal problems" (p. 186).

There is very little evidence about young children's interpretations about what science involves. However, participation in programs that, like the SLP, are thematically and conceptually coherent, include explicit focus on science as a process, and provide opportunities for cognitively guided learning and discourse about science, should shape the children's constructions of the meaning of science as well as their motivational beliefs related to the discipline. Researchers with the Integrated Science Literacy Enactments program (ISLE; Varelas, Pappas, Kane, Arsenault, Hankes, & Cowan, 2008) have explored children's ideas about science with students who participated in the program. In-depth interviews with three students in grades 2–3 highlighted changes in children's views before and after their participation in ISLE activities (Tucker-Raymond, Varelas, Pappas, Korzh, & Wentland, 2007). Children moved from describing science as an enterprise of making things to expressing 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 current study, we sought evidence of the meanings that kindergarten children constructed about science in SLP and regular classrooms, in addition to collecting quantitative data about their motivational beliefs. Further, we examine parallels between children's perceived competence and liking and their construction of the meaning of science in each setting.

## Science Instructional Practices and Sex Differences in Motivation

One reason given for differences in boys' and girls' liking and competence perceptions about science is their differential experience with science content and activities. For example, boys, relative to girls, tend to participate in more extracurricular science activities (especially related to physical science) (Catsambis, 1995; Greenfield, 1997), prefer science books more (Harkrader & Moore, 1997), receive more science and math toys (Jacobs & Bleeker, 2004), and are given more explanations by parents during visits to science exhibits (Crowley, Callanan, Tenenbaum, & Allen, 2001).

Traditional science instruction has been criticized for perpetuating the masculine stereotypes of science and scientists (Scantlebury & Baker, 2007). Additionally, the format and content of science lessons tend to be aligned with boys' instructional preferences, and less so with girls' (Koch, 2007). In general, boys enjoy competition, mechanistic topics, and de-contextualized activities, and they tend to dominate discussions and handling of equipment and materials. In contrast, girls tend to prefer doing science and making connections with what they learn. They also prefer instructional formats that involve interaction, discussion, and collaboration (Baker & Leary, 1995; Scantlebury & Baker).

In order to create learning environments that are equally facilitative for girls and boys, researchers have advocated that teachers use gender-inclusive practices for teaching science (e.g., Baker, 1998; Baker & Leary, 1995; Eccles, 1997; Koch, 2007; Parker & Rennie, 2002; Roychoudhury, Tippins, & Nichols, 1995), although there is not a consistent view of what comprises gender-inclusive curriculum and pedagogy (Brotman & Moore, in press). Nevertheless, practices common to most approaches involve forging girls' connections with the science content: making the relevance of science explicit to females' lives and everyday issues, emphasizing its social and environmental applications, expanding the science taught to include domestic and nurturing aspects of life, and depicting women as scientists. Indeed, addressing explicitly that women and people of color can be scientists and that science is practiced by all types of people is emphasized as being critical. Instructional activities requiring problem-solving, discovery, hands-on involvement, and sustained engagement with projects or issues over time are encouraged. Other gender-inclusive practices address the social environment within which instruction takes place: collaborative and cooperative group activities, student-centered discussion and sharing of ideas, gender-equitable language, ample wait time, supportive environments without ridicule, and competition not emphasized. The particular importance of social connections is often underscored, and is supported by Baker and Leary's finding that "relationships... provide the standard by which these girls [the $2^{nd}$, $5^{th}$, $8^{th}$, & $11^{th}$ graders in their study] make judgments concerning science" (p. 24).

Research on the effects of gender-inclusive instructional practices indicates promise, although the findings are not straightforward. When gender-inclusive practices are used, girls report greater motivation than those taught with more traditional science instruction, but only in some conditions. Furthermore, gender-inclusive practices appear to also promote boys' motivation for science, as well as girls'.

In some studies the gender gap in motivation, favoring boys, was eliminated after instruction that included gender-inclusive practices. For example, fourth and fifth grade girls' motivation increased after an activity-based unit on electricity; "Sex differences in attitudes about electricity that were present prior to the topic disappeared, demonstrating that girls enjoyed the unit considerably more than they anticipated they would" (Kahle et al., 1993, p. 391). Similarly, physics instruction that used jigsaw cooperative learning resulted in twelfth grade girls reporting greater competence in physics compared to girls who received direct instruction (Hänze & Berger, 2007). Boys' perceived competence, however, did not differ by type of instruction. The authors attributed the interaction between type of instruction and sex to girls having lower perceived competence than boys at the outset.

In contrast, other studies have found that the gender gap in motivation remained after gender-inclusive instruction. A study of eleventh graders learning physics found that when gender-inclusive practices and materials were used, boys and girls reported similarly greater interest and perceived competence, compared to those who received regular instruction (Labudde, Herzog, Neuenschwander, Violi, & Gerber, 2000). Therefore, although these practices benefited girls motivationally, they benefited boys equally.

Adding further nuance to the research, it appears that the size and sex composition (single sex vs. co-ed) of classes moderate the effects of the instructional practices used. Häussler and Hoffmann (2002) found that both adapting the seventh grade physics curriculum to girls' interests and training teachers to support girls' motivation did not prevent a decline in girls' (or boys') interest in physics across the year, similar to those who received traditional physics instruction. Dividing classes in half every other lesson (i.e., reducing class size), in addition to the previously mentioned strategies, did, however, result in girls not experiencing decreased interest in physics. The most advantageous outcome, though, was when classes were divided by sex every alternate lesson. In that situation, girls and boys maintained their interest in physics, with no difference by sex, and increased their perceived competence across the year; girls' competence perceptions increased particularly.

Studies of gender-inclusive instruction have been conducted with older children, particularly from middle school or later, and there is a dearth of research in the early elementary grades. Therefore, the extent to which these practices benefit kindergarteners is not known.

Another suggestion for equalizing boys' advantage in the science classroom is to use inquiry-oriented instruction (Shepardson & Pizzini, 1994). Integral to inquiry are many characteristics of gender-inclusive science instruction, including open-ended discussions that draw from students' ideas. Furthermore, it is ideally suited to accommodating all the other practices listed in the current section. Therefore, although inquiry is believed to be beneficial for both sexes, it may be especially so for females in terms of promoting enjoyment of and competence beliefs about science. There is some research to support this argument (Kahle et al., 1993), and we extend it in the current study by focusing on young children in kindergarten. We examine whether engaging in different types of science experiences (i.e., regular science lessons only vs. SLP activities) has differential effects for girls and boys. Specifically, we investigated whether girls' experiences with science inquiry and linked literacy activities in SLP attenuate any advantage in motivational beliefs that boys' experiences may afford. Thus, we investigated possible interactions between children's sex and the type of kindergarten science they experienced.

## Summary of Research Objectives

We sought to investigate whether sex or the type of science instruction kindergarten children receive is associated with differences in their motivation for science. Specifically, we examined whether kindergarten boys and girls: (a) differed in their perceived competence in and liking of science, (b) who engaged in SLP for either 5 or 10 weeks differed in their perceived science competence and liking compared to those who had a regular kindergarten science experience, (c) who engaged in SLP differed in the pattern of their motivational beliefs from those in regular science classrooms, and (d) who participated in SLP differed in their ideas about science from those who received regular kindergarten science.

## Method

### *Participants*

The participants were 162 kindergarten children (76 girls, 86 boys) from three schools in a mid-western, suburban public school district. Of the 160 children for whom lunch status information was available, 116 (71.6%) received free or reduced-cost lunch. Race/ethnicity information for the sample was: 96 (59.3%) Caucasian, 14 (8.6%) African American, 36 (22.2%) Hispanic, 9 (5.6%) "Other," and 7 (4.3%) Multiracial.

We conducted chi-square tests to see whether children's demographics differed across the three schools. There was no significant difference by school for free or reduced-cost lunch status ($\chi^2_{(4)} = 5.33, p > 0.05$), however the distribution of race/ethnicity was different ($\chi^2_{(8)} = 32.82$, $p < 0.001$). The percentage of Caucasian children within each school was similar (51.6–64.6%), but those from other racial or ethnic groups were not. In the school where kindergarteners received 5 weeks of SLP (SLP-5WK), 22% of the children were

Hispanic and 14% were Multiracial. In the school where kindergarteners received 10 weeks of SLP (SLP-10WK), 29.7% were Hispanic, 9.4% African American, and 9.4% "Other." And in the school where children received regular science instruction (REG), 12.5% of children were Hispanic, 16.7% African American, and 6.3% "Other."

The schools were adjacent to each other, no more than 2.4 miles apart. Before inviting teachers' and students' participation we reviewed the schools' socioeconomic and achievement characteristics, as reported by the state's Department of Education, to ensure their comparability. The three schools were attended similarly by ethnically diverse students, and relatively high numbers of students were living in poverty (43–51% of children received free lunch). At each school students' average performance on the state's achievement test was below the state average. For example, the proportions of students passing the 3rd grade English/Language Arts state test ranged from 57% to 64%, whereas the state average was 76%. The three schools were also similar across attendance rate (95.2–96.2%), stability, or percent of days enrolled (70.3–78.5%), number of children enrolled (221–412), and student-teacher ratio (14.3–14.9).

The children came from nine classrooms, taught by seven teachers. The kindergarten teachers' years of teaching experience ranged from 6 to 22 years in the SLP-5WK school, 1–19 in the SLP-10WK school, and 1–6 years in the REG school. With regard to science instruction, all teachers reported that they decided what science topics and activities they presented, and they were aware of the state science standards. All said they were never asked by administrators about science in their classrooms, although they were required to complete sheets recording time spent on reading and math each day. One teacher explained: "There are science standards, but... they're just there and they're not on their report card and so they're not really something that's a focus;" similar comments were made by the other six teachers.

Children in the REG group ($N = 49$) had a typical kindergarten experience, in that the greatest focus of their instruction was on literacy and mathematics. Science was typically incorporated in week-long themes (e.g., the seasons, animals), with content usually addressed in stories and art. This is consistent with documented patterns of science instruction within U.S. kindergartens (e.g., Weiss et al., 2003). Children in the SLP-5WK ($N = 61$) and SLP-10WK ($N = 48$) groups participated in SLP inquiry science and literacy activities. In the SLP-5WK group activities centered on living things and the butterfly life cycle over a period of 5 weeks, whereas in the SLP-10WK group activities were implemented for 10 weeks and involved units on living things and marine life. SLP science lessons lasted approximately 60 minutes, twice a week. An overview of SLP is presented later in this paper.

### *Measures*

*Beliefs About Learning Science.* We measured children's beliefs about learning science with the Puppet Interview Scales of Competence in and Enjoyment of Science (PISCES; Mantzicopoulos et al., in press). The items comprised descriptive statements referring to children's typical and familiar experiences during the SLP science activities. The pool of items was derived after both a review of items in self-concept and competence scales and value scales for young children (e.g., Chapman & Tunmer, 1995; Eccles et al., 1993; Harter & Pike, 1984; Marsh et al., 1998; Marsh, Ellis, & Craven, 2002), and classroom observations of the children as they were engaged in science inquiry and reading activities. Items involved a dichotomous format shown to be developmentally appropriate for assessing young children's beliefs (e.g., Marsh et al., 2002). We used bipolar statements (e.g., "I know how to do science" vs. "I don't know how to do science"), rather than a "yes/no" response format to questions or statements, to ensure that children understood both options. Agreement with positive items was scored 1 and agreement with negative items was scored 0. Scale scores were computed by averaging the items making up each scale (i.e., range is 0–1). Items and scales are shown in the Appendix.

The PISCES items are administered with two identical puppets, chosen by the child from a set of five ethnically diverse puppets, matched to the child's sex. After the puppets' introduction the children practice identifying which puppet "thinks the same" as him or her (e.g., to "I don't like pizza" vs. "I like pizza").

We then asked about children's conceptions of science. We prompted them to talk about science as follows: "In the school where ___ (Puppet 1) and ___ (Puppet 2) go they learn about science. Do you learn science in your school? What is science?" If a child said she or he does learn science, we then asked "What do you learn about in science?'', whereas we asked ''What might you learn about if you did have science?'' if the child reported not learning science at school. After the children had responded, follow-up prompts were: ''Anything else?'' or ''Is there anything else that you did in science?'' No other prompts were used in order to keep the administration time short and avoid taxing children's attention span. During administration in the first school (SLP-5WK) the examiners made notes of children's responses but not all responses were recorded verbatim. Our initial plan was to use these questions as prompts for children's event memories about science during the administration, and we had not considered conducting a narrative analysis of the data. We modified this procedure for children in the other two schools so that all examiners recorded children's responses verbatim.

After eliciting children's conceptions of science learning we read a common script that gave a brief overview of science topics. We did this to ensure that all children were familiar with a range of topics that may be part of learning science, and prevent them from responding to items without knowing what science involved. The script read: ''[Puppet 1] and [Puppet 2] have science in their kindergarten [too]. In science they learn about living things, the weather, the body, plants and animals, how things grow, how things move, and things like that. That's all part of science. [Puppet 1] and [Puppet 2] are going to talk about learning science, and I want you to tell me which one thinks the same as you.'' The researcher then administered the PISCES items by attributing the opposing statements about learning science to the two puppets. To control for order effects, the positive statements made by each puppet were counterbalanced so that each puppet made both positive and negative statements. In addition, the order of presentation varied so that each new item was not always presented first by the same puppet.

The *Perceived Science Competence* scale (7 items, $\alpha = 0.85$) assesses children's beliefs about their competence in science, both in terms of science in general and specific science knowledge and skills. The *Science Liking* scale (6 items, $\alpha = 0.82$) assesses children's enjoyment of learning about science and engaging in science activities. Evidence of convergent validity for the Perceived Science Competence and Science Liking scales comes from positive correlations with the Science and Applied Problems (math) subtests of the Woodcock-Johnson III Tests of Achievement (WJ-III; Woodcock, McGrew, & Mather, 2001); the correlations were higher with Science than with Applied Problems. Divergent validity evidence comes from low correlations with the WJ-III Passage Comprehension (reading) subtest (see Mantzicopoulos et al., in press, for further validity information).

We created two new scales to assess perceived competence in more specific aspects of science content and process. The *Science Process* scale (three items, $\alpha = 0.71$) assesses children's beliefs in their ability to ask science questions, make predictions, and keep records. The *Perceived Marine Life Knowledge* scale (three items, $\alpha = 0.63$) assesses children's perceived knowledge about animals that live in the water. The items about marine life were administered only to children in the REG and SLP-10W groups ($n = 97$). This was because only the longer, and not shorter, sequence of SLP activities addressed marine animals; children in the REG group learned about marine animals in their regular kindergarten science lessons.

*Observations of Science Lessons.* We video-recorded science lessons so that we could examine the nature and content of the science classes. In the REG group each teacher selected two different science lessons, typical for them, to be recorded. We recorded all SLP lessons. This enabled us to examine how the teachers instantiated the various SLP activities, given our ongoing development and refinement of activities. In the present study we use the video-recordings for an overview of science lessons in the REG classes.

*Teacher Interview.* We conducted semi-structured interviews with teachers to investigate aspects relating to their instruction, especially in science. The interviews lasted approximately 40 minutes, were audio-taped, and transcribed. In the present study we use information from the interviews in our description of the instructional contexts for the three groups of children. For the SLP groups we use data from teacher interviews about their science curriculum prior to the SLP intervention. We refer to REG teachers' responses to the questions that addressed: (a) descriptions of curricula, including science (e.g., ''What do you do for science in kindergarten?''), and, (b) rationales for their instructional choices for science (e.g., ''How do you figure out what to do and how much time to spend?'').

*Overview of Instructional Contexts*

Although a detailed analysis of the instructional contexts in SLP and REG classroom environments is beyond the scope of this paper, we provide an overview of the theoretical framework and principles guiding the SLP intervention as well as of the structure of the SLP activities, and comment on the comparability of the science instructional contexts for students in SLP and REG classrooms. For the SLP groups, we use information from the SLP teacher guides and the daily descriptions of science lessons implemented in each classroom, as well as comments made during teacher interviews. For the REG classrooms we use information from teacher interviews and lessons observed to document that SLP students participated in additional science instructional experiences, beyond those provided in their regular classroom curriculum.

*Theoretical Framework and Principles Guiding the SLP Intervention.* The development of SLP activities is grounded in research on human cognition and is guided by the view that science learning is a process of domain-specific knowledge construction (Brown, 1990, Carey & Spelke, 1994, Gelman & Brenneman, 2004). We view science learning as socially negotiated and situated in specific cultural contexts and practices (Rogoff, 1990; Roth, 2005). Following Giere (1988, 2002, 2004), we view science as a process of articulating, testing, evaluating, and refining or revising models of the world. We provide specific information about our theoretical and empirical approach to inquiry in Samarapungavan et al. (in press).

*Structure of SLP Activities.* SLP activities are built around science topics and skills linked to the state academic standards for kindergarten, and are mapped to Science, English/Language Arts, and Mathematics standards. They are also consistent with the National Research Council's recommendations for science (2000, 2001, 2007) and with current guidelines for developmentally appropriate practice as it applies to science instruction for young children (Chaille & Britain, 2003;NAEYC,2003;Worth & Grollman, 2003). 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.

All SLP units consist of integrated inquiry and literacy activities. The inquiry activities comprise a three-stage cycle (pre-inquiry, inquiry, and post-inquiry) structured to provide students with opportunities to be active learners (Samarapungavan, et al., in press). The goals of SLP inquiry units are to help students understand: (a) important themes or ideas in a scientific discipline in developmentally appropriate ways, and (b) the nature and processes of scientific inquiry. Inquiry topics are selected around key science themes (i.e., growth and development, biological adaptation, life cycles) and address meaningful phenomena for children who can use their knowledge and experiences to ask questions and make predictions about the natural world. They then try to answer those questions by conducting investigations where they observe, record, infer, draw conclusions, and communicate findings. Extension activities within each unit promote conceptual understanding and integrate science, language, and math learning. Children use science notebooks to draw pictures, write, and paste digital photos in, and to show later to family members. Along with the science inquiry activities, teachers engage children in interactive science book readings on themes related to the inquiry activities. The reading program is based on informational texts for young children and emphasizes dialogic reading strategies (Whitehurst et al., 1999).

*Activities in the SLP-5WK and SLP-10WK Schools.* Prior to the SLP intervention, the emphasis on science learning and instruction in the SLP schools paralleled those observed in the regular classrooms. This conclusion is based on data obtained during informal discussions with the SLP teachers, individual interviews, and baseline video-recordings conducted prior to the SLP activities. During the interviews all teachers told us that, before beginning SLP, science involved stand-alone lessons relating to week-long themes such as seasons, Halloween (i.e., pumpkins), and farm animals. Unlike the heavy focus on literacy and math, teachers said they were not asked to schedule science regularly or document science instructional time, and there was no standard allocation or minimum time required for science. Nevertheless, teachers told us they tried to include science during most weeks. During the school year teachers in both SLP groups implemented the SLP science activities, in addition to other science activities that had been part of their regular curriculum (e.g., farm animals, hygiene, fire safety). An SLP graduate student aide assisted the teachers in the implementation of the SLP activities. All science lessons were videotaped and lasted approximately 60 minutes, twice a week.

Within the context of SLP, teachers taught a series of science lessons associated with life science units (see Table 1 for a summary of activities). Specifically, teachers in the 5-week sequence (SLP-5WK) piloted activities on living things and the life cycle of the butterfly; activities were based on observation of animals and plants in the children's environments. In the 10-week sequence (SLP-10WK) we extended the living things activities into a 4-week unit, followed by a 6-week unit on marine life that involved observations of organisms in a saltwater aquarium. Concepts covered in the 5-week living things and butterfly life cycle unit were included and expanded in the 10-week living things and marine life sequence. Key concepts across these life science units for both SLP groups, documented in the video recordings, involved differences between living and nonliving things, habitats and adaptation, animal structures and their function, and life cycles. Activities concurrently addressed concepts involving the nature of science (asking questions, making predictions, conducting observations, and using tools to observe and record findings). Children actively made observations and recorded them, took measurements, drew and wrote in their notebooks, and used tools (e.g., magnifying glass). Although the children did not choose the activities, they had input into the questions they asked, what they observed, and the content of their discussions. Book readings paralleled the themes of the inquiry activities. Despite the considerable overlap between the two SLP groups in concepts covered in the activities and readings, there were significantly more opportunities for children in the 10-week group to interact with the content and extend their learning and conceptual understanding across different inquiry activities, readings, and contexts.

*Science Experiences in the Regular (REG) Classrooms.* 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,

Table 1
*Outline of concepts and inquiry activities covered in the SLP lessons*

| Concept | Description of Inquiry Activities | SLP—5WK | SLP—10WK |
|---|---|---|---|
| The nature of science | Predictions | X | X |
| | Observations | X | X |
| | Recording | X | X |
| | Using tools (science notebook, ruler, magnifying glass) | X | X |
| | Measurement | X | X |
| Properties of living things | Discussion (predictions, observations about living things) | X | X |
| | Nature walk (observe, identify living things in their natural habitat) | | X |
| | Draw a living thing | | X |
| | Plants as living things—experiment on plants and discussion on movement | | X |
| | Habitats for living things | X | X |
| | How living things breathe | X | X |
| | How living things respond to their environment | X | X |
| Life cycle of the butterfly | Observations of caterpillar/chrysalis/butterfly | X | |
| | Adaptation, predator prey relations, camouflage | X | |
| | Post-inquiry poster and discussion | X | |
| Marine life | Marine animals as living organisms (Is it a living thing?) | | X |
| | The aquarium as a model of ocean habitat (making predictions—what lives in an ocean?) | | X |
| | Observations of marine animals | | X |
| | What is the ocean like? (Making sea water; marine habitats) | | X |
| | Structure and function (features of different marine animals and the functions they serve) | | X |
| | Adaptation, predator prey relations, camouflage | | X |
| | Post-inquiry poster and discussion | | X |

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.

Teachers decided what science they taught, making decisions according to what they thought children would be interested in or what they had enjoyed in previous years. They 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. The science classes we observed included lessons on health and germs, pollution and recycling (on Earth Day), light and shadows, and teeth and dental hygiene.

Teachers told us that providing hands-on science learning was an objective for them. Science lessons were not inquiry based, however, according to their descriptions and our observations of a range of typical science activities. Activities 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), using their hands to make patterns from shadows, and pasting mini marshmallows onto paper to make a mouth of teeth.

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''). 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.

### *Procedure*

Researchers administered the PISCES scales to children individually in a quiet room during regular school time. Administration occurred at the end of the science units for children in the SLP-5WK and SLP-10WK groups (December and April, respectively), and in April for children in the REG group.

We video-recorded the SLP lessons as they were taught throughout the school year. We recorded the REG science lessons during the spring semester, whenever the teachers scheduled them. We interviewed the teachers individually near the end of the school year, after all the lessons were recorded.

## Results

The objectives of the current study were to investigate whether children's beliefs about science differed by their type of science experience, by sex, and the interaction of experience type and sex. We first examined the quantitative data to investigate motivational beliefs about learning science. We then used qualitative data to examine children's constructions of science, and the extent to which these constructions paralleled their motivational beliefs.

## Quantitative Data

### *Ratings of Motivational Beliefs*

In considering the children's responses to the PISCES scales of motivational beliefs we first examined the descriptive statistics for the entire sample. The mean scores across the three perceived competence measures were just above the mid-point; $M$s $= 0.51$, 0.59, and 0.62, for perceived marine life knowledge (SD $= 0.40$), science process (SD $= 0.39$), and perceived science competence (SD $= 0.35$), respectively. The mean for science liking was higher ($M = 0.73$; SD $= 0.32$). Skewness statistics ranged from $-0.09$ (perceived marine life knowledge) to $-0.94$ (science liking); that is, not outside skewness guidelines for indicating normality (Curan, West, & Finch, 1996).

Next, we computed a 2 (Sex) $\times$ 3 (Experience: REG, SLP-5WK, SLP-10WK) Multivariate Analysis of Variance (MANOVA) to examine differences by sex and type of learning experience. This analysis was conducted with all children and did not include perceived marine life knowledge. Data on the latter subscale were collected only with children in the REG and SLP-10WK groups. In order to consider perceived knowledge of marine animals, we ran a separate 2 (Sex) $\times$ 2 (REG or SLP-10W) MANOVA with the marine life subscale included in the list of outcomes.

To pinpoint the source of significant MANOVA effects for the type-of-experience variable, we examined the results of univariate ANOVAs. Following significant F-statistics, we conducted a pairwise contrast analysis to identify differences between type-of-experience groups (REG, SLP-5WK, SLP-10W). In addition, we tested contrasts for linearly increasing trends across the three experience groups using weights for a three-group trend analysis of linearly increasing relationships (Marascuilo & Serlin, 1988).

### *Are There Differences in Young Children's Beliefs About Learning Science by Sex and Type of Learning Experience?*

The multivariate effect for type of science experience was significant $F(3,151) = 42.52$, $p < 0.001$, suggesting differences between the three experience groups across the motivational beliefs subscales. Although the effect of sex was not significant, there was a significant multivariate interaction effect for sex by type of experience, $F(3,151) = 3.46$, $p < 0.05$. The results were comparable for the MANOVA that was conducted to evaluate group differences when the perceived marine life knowledge subscale was included, $F(4,89) = 33.36$, $p < 0.001$. Significant univariate effects, including effects from the analysis for the measure of marine life knowledge, supported differences by type of experience across all subscales. In addition, the univariate statistics indicated that the significant multivariate interaction effect (sex by type of experience) was due to mean differences in sex by type of experience for the science liking subscale.

We next report results by perceptions of science competence, competence in science process, marine life knowledge, and science liking, and show descriptive and univariate F statistics by type of science experience in Table 2. We also show boys' and girls' descriptive statistics for each subscale and type of science experience in Table 3.

*Perceived Science Competence.* Children differed in perceived science competence depending on their science instruction type, $F(2,154) = 60.96$, $p < 0.001$. Overall, children who participated in SLP reported having greater competence in science than did children who had the regular kindergarten experience. For the science competence measure, all post-hoc pairwise contrasts between the three experience groups were significant and there was a linearly increasing trend across the group means associated with type of experience. The interaction of sex by instruction type for this measure was not statistically significant.

*Science Process.* When beliefs about the process of science were considered, children differed in their perceived competence depending on the type of their science instruction, $F(2,152) = 19.58$, $p < 0.001$. All post-hoc pairwise contrasts between the three groups were significant and there was a linearly increasing trend in the group means associated with type of experience. Children in the REG group had the lowest mean, followed by children in the SLP-5WK group, and the SLP-10WK group.

*Perceived Marine Life Knowledge.* There was a significant difference in perceived knowledge about marine life depending on the type of children's science instruction, $F(1,96) = 66.83$, $p < 0.001$. Children who engaged in the marine life unit of SLP reported knowing more about animals that live in water than children with the regular kindergarten experience did.

Table 2
*Descriptive and F statistics of science motivation measures by type of science experience*

| | Regular Science | | SLP—5WK | | SLP—10WK | | |
|---|---|---|---|---|---|---|---|
| | *M* | SD | *M* | SD | *M* | SD | *F* |
| Perceived science competence | $0.27_a$ | 0.25 | $0.72_b$ | 0.30 | $0.86_c$ | 0.21 | $60.96^{***}$ |
| Science process | $0.34_a$ | 0.35 | $0.65_b$ | 0.38 | $0.78_c$ | 0.30 | $19.58^{***}$ |
| Perceived marine life knowledge | $0.24_a$ | 0.32 | | | $0.79_b$ | 0.27 | $66.83^{***}$ |
| Science liking | $0.47_a$ | 0.32 | $0.81_b$ | 0.26 | $0.89_b$ | 0.24 | $29.30^{***}$ |

*Note*: Means with different subscripts differ significantly at $p < 0.05$.
$^{***}p < 0.001$.

Table 3
*Descriptive statistics of boys' and girls' science motivation measures by type of science experience*

| | Regular Science | | | | SLP—5WK | | | | SLP—10WK | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Boys | | Girls | | Boys | | Girls | | Boys | | Girls | |
| | *M* | SD | *M* | SD | *M* | SD | *M* | SD | *M* | SD | *M* | SD |
| Perceived science competence | 0.29 | 0.24 | 0.26 | 0.26 | 0.71 | 0.30 | 0.73 | 0.31 | 0.88 | 0.17 | 0.81 | 0.27 |
| Science process | 0.35 | 0.38 | 0.33 | 0.34 | 0.54 | 0.40 | 0.78 | 0.32 | 0.80 | 0.29 | 0.75 | 0.33 |
| Perceived marine life knowledge | 0.32 | 0.34 | 0.19 | 0.30 | | | | | 0.83 | 0.23 | 0.71 | 0.34 |
| Science liking | 0.59 | 0.28 | 0.39 | 0.32 | 0.77 | 0.29 | 0.85 | 0.23 | 0.88 | 0.25 | 0.92 | 0.21 |

*Science Liking.* There was a significant difference in liking science depending on the type of science instruction children received, $F(2,152) = 29.30, p < 0.001$. Follow-up contrasts confirmed that REG children differed significantly from their SLP peers in both the 5- and 10-week groups. The contrast examining differences between the two SLP groups was not significant, although the linearly increasing trend in the group means for liking by type of experience was supported by a significant statistic.

The interaction between type of experience and sex had a significant effect on science liking, $F(2,152) = 3.82$, $p < 0.05$. This interaction is shown in Figure 1. Within the group of children who experienced the regular kindergarten curriculum, boys expressed liking science more than girls did (*M*s = 0.59 and 0.39, respectively). However, boys and girls who participated in SLP reported liking science equally regardless of SLP group (*M*s = 0.77 and 0.85, for SLP-5WK boys and girls respectively; *M*s = 0.88 and 0.92, for SLP-10WK boys and girls, respectively).

## Qualitative Data

### *Children's Narratives About Science Learning*

*Coding Scheme*: To document children's construction of the meaning of science as an academic subject, we examined differences between the SLP-10WK and the REG groups' responses to the two questions about

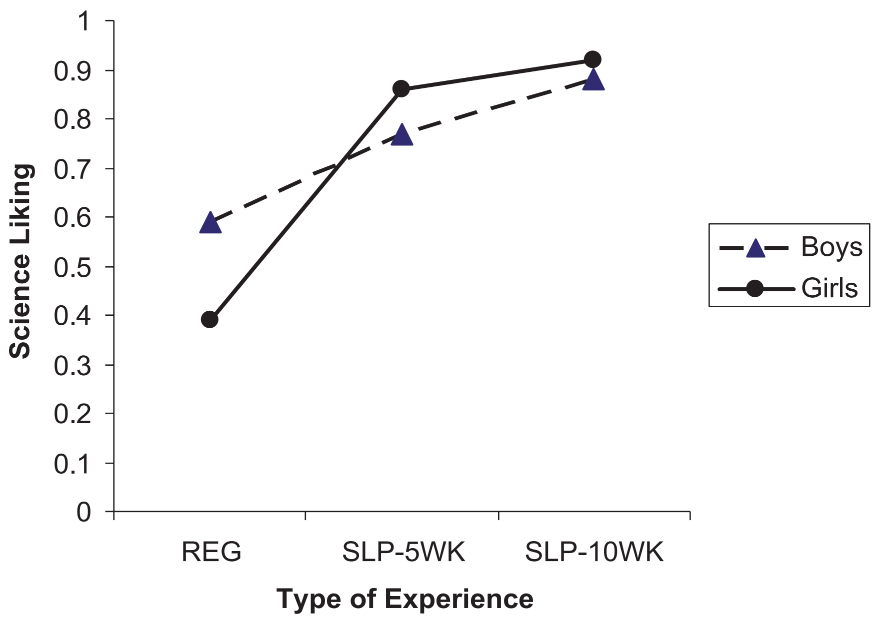


*Figure 1.* Boys' and girls' science liking by type of science experience.

learning science in school (i.e., "What do you learn in science?" and "What is science?"). The second question was not intended as a prompt for young children's epistemological beliefs about science, but rather as an additional probe that would provide access to their experiences and event knowledge. We began this process with the SLP-5WK group, developed a coding scheme, and then applied it to the verbatim-recorded responses of children in the other two schools (i.e., SLP-10WK and REG).

In the process of developing the coding scheme we found that answers to the two questions were not independent; children often continued with their comments in response to the second question, or expressed that their first answer also addressed the second question. For example, they often made comments such as "That's all" or "That's all I know" after the second question. Therefore, we coded children's responses to both questions together.

There were two types of responses; children either did or did not know about science. Accordingly, we created two categories for coding the descriptions: (1) Don't know about science, and (2) Described or listed some aspect of science. The two categories are shown below, with examples from the SLP-5WK group.

1. *Don't know*: This includes comments such as "I don't know" or "can't remember," or no response, or responses not related to science (e.g., "learn how to sing ABCs" or "School, toys, cars").
2. *Descriptions of science vocabulary, content, activities, or processes*: Examples are, "Rain, sun, and clouds," or "Being healthy," or "I learned about butterflies. Instead of chrysalis, people sometimes call it a cocoon," or "I learned about the magnifying glass. . .when you put it real close you see it big," or "Science is when you investigate."

The first and second authors used this coding scheme to independently code the responses of children in the SLP-10WK and REG groups. Inter-rater agreement was 98.7%.

*Are There Differences in Young Children's Constructions of Science by Type of Learning Experience and Sex?*

We first compared the number of children from each group who knew about science. A greater percentage of children who engaged in the SLP activities gave a description of science that indicated they had constructed meanings about the discipline, compared to those who received regular science instruction; ($\chi^2_{(1)} = 21.54$, $p < 0.001$). Of the 49 children who received the regular science instruction, only 17 (35%) mentioned science content. However, 39 of the 48 (81%) children who participated in the 10-week SLP activities mentioned science content in their narratives. The percentages of girls and boys in the REG and SLP-10WK groups whose comments contained reference(s) to science are shown in Figure 2.

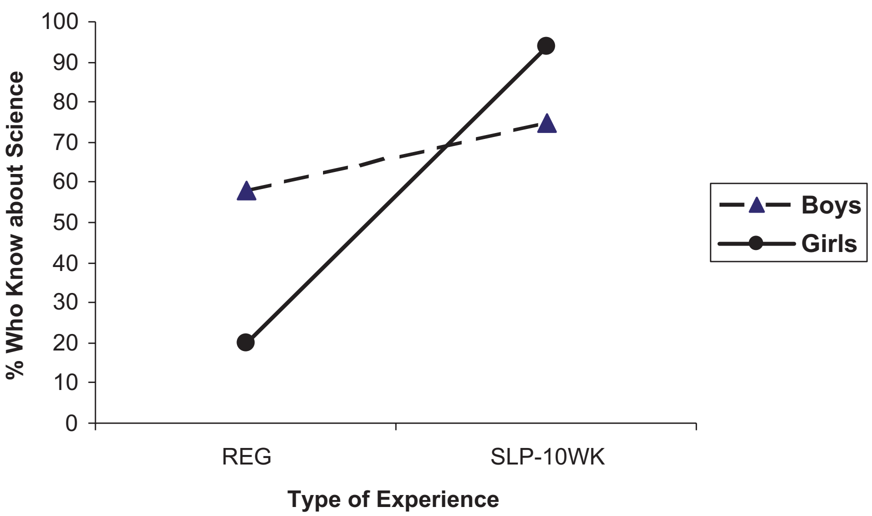


*Figure 2.* Boys' and girls' knowledge about science by type of science experience.

*Regular Science Experience.* Within the group of children who received regular science instruction, a greater proportion of boys, compared to girls, knew about science; ($\chi^2_{(1)} = 7.37, p = 0.007$). Eleven of the 19 boys (58%) knew something about science. Interestingly, five of their descriptions mentioned potions. The following are examples of their narratives:

> Science is like when you have potions and stuff and they turn into different things.
>
> Science is learning about stuff like being a Doctor when you grow up or how to be a science teacher.
>
> You have to be big to do science. If you're little, you'd get hurt. Do stuff with chemicals, like mix them up together and they'd blow up.
>
> When a person has stuff and they pour it together and it blows up. You wear a mask to see and you use a towel to clean up.
>
> I do it at home. My brother, 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.
>
> They can make 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 Pedro goes on the bus to do science. He's 12.

Only 6 of the 30 girls (20%) gave descriptions that indicated knowing about science. Their responses most commonly referred to making things, including robots and computers; only one girl mentioned potions. Examples of girls' narratives are:

> How to make a robot and computers.
>
> They would have to make potions or put one potion in another to make a rainbow potion.
>
> It's not for kindergarten. It's for big people. I really hope I can make stuff out of science, like flowers.
>
> How to make a penguin. And a hawk. They're hard to make.
>
> You make stuff. Electric stuff, like electric robots. How to make a robot and computers. You can make doggie robots.

*SLP-10 Week Experience.* There was no difference between the proportions of girls and boys who knew about science for children who received 10 weeks of SLP; ($\chi^2_{(1)} = 2.46$, n.s.). Specifically, 24 of the 32 boys (75%) and 15 of the 16 (94%) girls included reference to science content in their narratives. Both boys' and girls' narratives contained lists of things from content covered in the SLP living things and marine life units. These lists included content-related vocabulary (e.g., starfish, shells, polar bears, anemone, clownfish, damsel, breathe, excrete, eat, interact, develop, camouflage), factual information (e.g., "fish breathe," "fish. . .they have bones in them," or "fish, they live under water"), as well as routine activities that they engaged in during science (e.g., conducting experiments, recording observations in the science notebook, reading science books). None of the descriptions referred to potions, robots, or danger. The following are examples of boys' narratives:

> Fish, they breathe though gills and anemones eat shrimp.
>
> You took pictures of those animals and wrote in journal. You make some experiments.
>
> Living things. They move and breathe.
>
> Interact. Excrete. Develop. Living. Growing. Clownfish. Anemone. Damsel fish.
>
> People do science stuff to help them to know about things that lives - live in shells, like snails, crabs, and turtles.

Examples of girls' narratives are:

> Living things. They move, breathe, blend in.
>
> Science is about learning and about being healthy. Learning about how fish breathe and swim.
>
> Fish. Living things. Dog. Because they breathe, excrete, grow, have puppies, feed.
>
> Living things, polar bears, cattails are living. Cars are not living.
>
> You have these journals that you keep notes in. And sometimes you interact with the environment.
>
> It's like fish and other fish, and they get moved together. They hide and blend in with the environment, and see, and poop.

In summary, the children's constructions of science parallel closely their perceived competence for, and liking of, learning science. The SLP children's narratives also indicated they had a better idea of what science involved, compared to those receiving regular instruction. Additionally, REG children's descriptions most often mentioned potions, and engineering-type construction (e.g., computers, robots). Among those in the REG group, boys reported significantly more knowledge about science than did girls. However, this sex difference was not present for children who received SLP; boys' and girls' narratives contained comparable descriptions of science content and activities. Furthermore, their descriptions of science most often referred to living things—either general characteristics or specific examples of living things.

## Discussion

Our results provide new and valuable information about the relations among young children's motivation for science, types of early experience with science at school, and sex differences. First, we extended previous research by providing additional evidence that sustained and meaningful participation in science activities is related significantly to children's beliefs about their competence in science processes and skills, their liking of science, and their views of what learning science encompasses. Second, we found evidence of sex differences in kindergarten children's motivation-related beliefs. Although boys and girls felt equally competent about their science knowledge and skills, regardless of their type of learning experience, the link between the nature of early science activities and liking science was different for boys and girls. The sequences of integrated inquiry and literacy SLP activities were especially beneficial for girls' interest and liking. Moreover, the link between the nature of early science activities and constructions of what science involves was also different for boys and girls. Again, girls were especially advantaged with SLP activities.

### *Early Science Experience and Young Children's Motivational Beliefs*

Children who experienced the regular kindergarten science curriculum reported relatively low levels of perceived competence in science, and moderate levels of liking science. On the other hand, children with the same demographics who participated in the SLP program of inquiry and literacy-based science expressed, on average, significantly greater perceptions of competence in, and liking of, science. Moreover, children who participated in the SLP program for 10 weeks expressed more positive beliefs about their science knowledge and their ability to do science, compared to their peers in the other two groups. These findings are noteworthy because students who enjoy a subject and believe they are good at it exert more effort, invest more time, and achieve at higher levels. Indeed, positive motivation and emotions are powerful predictors of subsequent engagement, effort, and achievement (Eccles et al., 1998). Conversely, negative beliefs and emotions, such as a lack of confidence in one's ability or feelings of disinterest or boredom, "can overwhelm thinking and concentration so that intellectual efforts are swamped and rendered wholly ineffective" (Alsop & Watts, 2003, p. 1043) or they may precipitate avoiding the activities altogether.

We also found significant differences in kindergarten children's views of science, depending on whether they had experienced regular science instruction only, or the SLP science activities. 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, though, from both our videotaped observations and teacher interviews, that the children did participate in a number of different science activities. However, they were taught as stand-alone topics without an explicit focus on science learning as a process of constructing, evaluating, and sharing knowledge. Lessons did not involve explicit science discourse and, although 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 suspect that this is why the majority of the children receiving regular instruction did not express awareness that they learned science in kindergarten. Furthermore, it appears that without the sustained, conceptually coherent sequences of science activities, children drew from other experiences and images when constructing notions about what science involves.

The contexts for science instruction in the regular and SLP classrooms provided different opportunities for children to engage with science. Although reality constraints did not permit the random assignment of children to the different types of science instruction or length of SLP, we did document that the children, classrooms, and schools were comparable across the three conditions. Thus, the quasi-experimental design of this study allowed us to directly examine the motivational beliefs of comparable groups of children who learned science, either during regular kindergarten science lessons or in the Scientific Literacy Project. We argue that the differences favoring the SLP group were not simply the result of providing children more time on science tasks. Indeed, children in the regular science classes also had science lessons; some weeks they learned science every day, whereas this was not the case in SLP classrooms. Children in the SLP classes generally had science twice a week during the length of the units (5 or 10 weeks). In explaining the differences between the two types of experience, therefore, we believe that the nature of the science lessons was a critical factor. Science educators advocate that activities such as posing meaningful questions, formulating hypotheses, conducting and recording observations, and making sense of results are a fundamental means of promoting children's interest and excitement in science, and their belief that everyone can be good at science (National Research Council, 2000, 2001, 2007; Worth & Grollman, 2003). Participation in the longer (10-week) sequence of SLP activities represents steps toward this goal through affording children multiple and interrelated opportunities to engage with science for nearly a semester. Therefore, our results provide support for recommendations to implement developmentally appropriate early science education programs—something that is especially sparse across the nation.

Our findings are consistent with reports about positive changes in older students' attitudes as a result of participation in science programs that, like SLP, involve hands-on exploration with meaningful materials, emphasize dialogically oriented classroom discussion, and make science exciting (Varelas & Pappas, 2007; Vargas-Gomez & Yager, 1987). They are also in line with research on literacy instruction with young children, whereby the types and variety of tasks that teachers use, as well as the amount of time they allocate to activities, communicate to children how much those tasks are valued (Nolen, 2001). Thus, the nature and extent of SLP activities arguably communicated to the kindergarteners that science is worthwhile, exciting, and not too difficult or out of reach for them, in addition to conveying a salient and realistic notion of what science involves.

Children in the regular kindergarten classrooms also had science lessons; their teachers provided children with several stand-alone science experiences during the school year. That is, their curriculum included isolated instruction in science topics at different times during the year, mostly in the context of cultural or seasonal events. However, there was no evidence of conceptual coherence or continuity across science topics—a situation entirely consistent with national trends reported early in this article (e.g., Fulp, 2002; Lanahan et al., 2006). Our findings provide support for claims (e.g., Worth & Grollman, 2003) that isolated pockets of exposure to science that lack conceptual coherence are not likely to promote the development of children's knowledge, skills, and positive motivational beliefs.

Despite the indications that children's experience with the SLP activities was associated with greater perceived competence in and liking for science, the claim that SLP activities were responsible for these greater motivational beliefs is made with some caution. We did not take pre-test measures of children's motivation, and therefore cannot determine whether the three groups' motivation for science was equal before the science instruction. However, it is not clear that pre-testing children about their science motivation is a fruitful endeavor considering recent evidence that only a minority of children have an understanding of science at the beginning of kindergarten (Mantzicopoulos et al., 2008). Furthermore, the comparability of the groups on achievement, socio-demographic, classroom, and school characteristics provides considerable support to the assertion that the findings are associated with the children's instructional experiences across the three contexts (REG, SLP-5WK, SLP-10WK).

### *Sex Differences in Motivational Beliefs*

The results of our study also speak to the dilemma of the under-representation of females in classes and careers related to areas of science, technology, and engineering. The girls and boys in the present study reported feeling equally able and competent at science in general, and with the process of doing science. This is an important finding, given numerous studies showing that boys in the middle grades tend to believe they are better at science than do girls. Our study, therefore, suggests that researchers must focus their attention on the period between the early elementary and middle school years in order to understand more about when, and in what circumstances, the divergence in boys' and girls' perceived competence typically occurs across different domains of science.

We identified an interesting interaction between sex and type of learning experience for liking science. Boys who experienced the regular kindergarten science instruction reported liking science significantly more than did the girls. However, in the SLP groups there was no difference between boys' and girls' liking of science. This finding has important implications for science learning, particularly in light of evidence about young children's early sentiments about school. Ladd, Buhs, and Seid (2000) have shown that kindergarteners' negative feelings about school early in the year are related to less engagement in classroom activities, and lower achievement by the end of the year. Thus, an early dislike of science bodes poorly for later engagement and achievement.

Our observations of the regular science classes did not indicate aspects of the lessons or instructional environment that may explain why boys enjoyed science more than girls. Children sat as a whole class on the carpet or worked individually at their desks, and activities included art or listening to the teacher reading story books—activities that would not be expected to appeal more to boys. It may be that science in the regular classes was disconnected and not salient as "science," so that, when thinking about science, the children referred to conceptions developed from out-of-school experiences (e.g., interactions with parents or other children, television shows, movies). When it comes to science, parents of young children tend to explain more to boys than to girls (Crowley et al., 2001), a finding that confirms assertions that out-of-school experiences tend to socialize girls away from science (Koballa, 1995). Therefore, this sex difference in regular kindergarten classes has drastic implications—if girls begin school already tending to not like school science, and science instruction accounts for little time and involves stand-alone activities and disconnected topics, then they are less likely to engage conceptually and affectively with science content and to be well poised for later success in science.

In contrast to the sex difference for liking science in classes with regular science instruction, boys and girls in the SLP classes expressed they liked science equally highly. Furthermore, SLP girls liked science more than did boys who experienced only the regular science lessons. This is a crucial finding; it suggests that providing regular opportunities to interact with meaningful integrated science inquiry and literacy activities, that are part of the curriculum over the course of the school year, may avert the pattern of boys enjoying science more than do girls. Enjoyment or liking a subject is vital—it is one of the most important predictors of students' choice of advanced classes, tertiary qualifications, and careers, including those in science and technology-related areas (Eccles, 1994, 2007).

Paralleling the results of the science liking data, the link between sex and constructions of what science involves depended on the type of science instruction the children experienced. In the regular classes only a small portion of girls, but significantly more boys, identified an aspect of science. However, both girls and boys who experienced SLP activities were equally knowledgeable about science. Thus, although SLP instruction was associated with all students forming accurate conceptions of science, it was especially beneficial for girls, seemingly eliminating the gender gap. This finding also supports the position that, in the absence of a coherent and sustained program of science instruction, young children learn the typically gendered views of science commonly presented in society.

Our study does not indicate the reason(s) for the sex by science experience interactions. Perhaps the emphasis on dialogic interactions in SLP lessons led to girls receiving a more equitable share of teacher attention or access to materials. Perhaps girls liked science as much as boys after SLP activities because girls gained a clearer conception of what science entails—that it is not limited to dangerous and solitary activities, such as mixing potions or creating dastardly inventions, as is commonly portrayed in children's television shows, movies, and books. Or perhaps the inclusion of high-quality and highly appealing non-fiction science books was especially enticing to girls. The content, quality, and type of text shape children's interests and understanding (Teale, 2003), and it has been suggested that girls, who generally have strong reading skills, might be positively affected by the inclusion of informational science literature in the curriculum (Ford, Brickhouse, Lottero-Perdue, & Kittleson, 2006). In light of the overlap between gender-inclusive practices and the SLP inquiry and literacy activities, our findings also support claims (e.g., Baker, 1998; Koch, 2007) about gender-inclusive instruction as a way to promote girls' enthusiasm and motivation for science. Most likely, there are many inter-connected factors, with not all being equally important for all girls—or all children. Researchers may wish to attempt to tease apart the relative effects of the inquiry and the literacy activities in future studies. However, given both the very real time constraints and the prominence of literacy instruction in the early years, such results may be of limited practical usefulness.

*Implications and Directions for Future Research*

All SLP science units involved topics within life science. Given the suggestions that sex differences are greater for physical science (Andre et al., 1999; Koballa, 1995) and that science is a field with diverse disciplinary content, it will be important to continue to explore the origins of sex differences across additional science domains and topics.

Researchers will also need to carefully examine classroom processes, including teacher practices and child behavior, to identify the extent to which teachers' use of practices advocated to enhance science inquiry, dialogic reading, and gender-equity are associated with children's motivation. Are all practices equally effective or are some more necessary than others? How do they play out with kindergarteners and what are the challenges?

We considered whether children benefited motivationally from engaging in integrated inquiry and literacy activities. We expect that, in the future, researchers will also want to consider indicators of learning; this seems to be under-investigated in the early grades. Additionally, following from the interaction between sex and type of science experience in relation to motivation, we expect that researchers will be interested in investigating whether there are differential benefits for girls' science learning, relative to boys'.

This current study raises questions also about possible outcomes with older children, such as those in first or second grade. In particular, it would be of interest to examine whether there is a sex difference with liking science in these next grades, and whether inquiry and literacy-related science activities mitigate this difference to the same extent. That is, if girls continue through kindergarten and first grade believing they do not really like science, will they be as amenable to changing those beliefs if they experience integrated science inquiry and literacy in second, third, or fourth grade? And what about children who participated in these activities during kindergarten, but whose first grade science was more typical (i.e., sporadic, disjointed, focused on science facts, art, and fiction, but not on science as a process of asking and answering meaningful questions)—will their motivation for science stay positive or be affected adversely?

The results of our study provide strong support for including science as part of young children's regular school experience. This is no easy assignment, but, if the payoffs include children feeling more confident about their ability to learn science, and expressing greater interest in science—especially girls—then the rewards are likely to be substantial.

The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant #R305K050038 to the authors. The opinions expressed are those of the authors and do not represent views of the U.S. Department of Education. We greatly appreciate the involvement of the teachers and children in this study. We also thank Glyndis Dean, Lisa Duffin, Karleah Harris, Kiana Johnson, Amber Soeters, Anna Strati, Adrian Thomas, Carla Gerberry, Sarah DeLeeuw, Sybil Durand, and Traci Hemmer for their assistance with this study, and the editors and reviewers for their feedback.

## Notes

[1]We use Rennie's (1998) distinction "between sex, which is biologically determined, and gender, which is a sociological label referring to those non physiological components of sex that are culturally regarded as appropriate to males and females" (p. 952; see also final paragraph of p. 952–953). Additionally, we share the view that "*sex* inequities are largely rooted in socially and culturally constructed ideas about *gender*" (Brotman & Moore, in press).

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## Appendix

Puppet Interview Scales of Competence in and Enjoyment of Science (PISCES)

| |
|---|
| Perceived science competence |
| I know how to do science |
| I know why living things camouflage |
| I can do science |
| I know how to use different science tools |
| I know a lot about different kinds of living things |
| I know a lot about science |
| I can remember new science words |
| Science liking |
| I like science |
| I want to know more about science |
| I feel happy when I am learning science |
| I have fun learning science |
| I like to write in my [a][a] science notebook |
| I like using different science tools |
| Science process |
| I know how to ask questions like a scientist |
| I am good at making predictions |
| I know how to use my [a][a] science notebook |
| Perceived marine life knowledge |
| I know how fish breathe |
| I know why an anemone is a living thing |
| I know how a hermit crab camouflages |

*Note*: Items involve opposing positive and negative statements, however only the positive are shown here.

[a]Children in the regular classes were asked about "a science notebook", not "my science notebook."