Science
Education

Longitudinal Analysis of the Relations Between Opportunities to Learn About Science and the Development of Interests Related to Science

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ABSTRACT: Relations between parental reports of children's interests related to science and opportunities for science learning were examined longitudinally in 192 children between ages 4 and 7 years. Science interests were tracked during 1-year periods (ages 4–5, 5–6, and 6–7) and were more prevalent among boys, particularly prior to age 6 years. Gender differences did emerge in terms of frequencies of opportunities for science learning during all 3 years. Longitudinal path analyses tested relations between children's science interests and their opportunities for science learning. Our data suggest that early science interests were strong predictors of later opportunities to engage in informal science learning, whereas the opposite pattern (early opportunities predicting later science interests) was not found. Young girls' expressed science interests led parents to subsequently increase opportunities for science learning during the following year. Although boys followed this pattern early in the study, over time boys received similar levels of science opportunities regardless

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of their interest. Bases for gender differences in early science interests and implications for later science learning in school are considered. *Sci Ed* **96:**763–786, 2012

INTRODUCTION

Considerable potential for preschoolers' informal science learning exists within the everyday routines of home and family (Callanan & Jipson, 2001; Crowley & Jacobs, 2002; Korpan, Bisanz, Bisanz, Boehme, & Lynch, 1997). Parents may choose to enhance these experiences by acquiring toys, electronic media, and books focused on scientific phenomena for their children. Yet it is unclear to what extent these opportunities for learning about science relate to science interests among young children, or the expression of future interests.

To answer this question, we longitudinally examined the relation between early science–related opportunities provided in the home and community and the occurrence of science-related interests between the ages of 4 and 7 years. Below, we begin with a brief review of the literature on children's informal science opportunities followed by literature examining children's interest in science, particularly gender differences. We then address potential linkages between parent-provided opportunities and interest development in young children.

Early Science Opportunities

Children can be introduced to the world of science as they explore the natural world, read books and interact with digital media related to science, and conduct simple observational studies and experiments. Parents can play a pivotal role in introducing children to science through trips to museums, reading relevant books, and responding to everyday questions (Crowley, Callanan, Jipson, et al., 2001; Tenenbaum, Snow, Roach, & Kurland, 2005). Callanan and colleagues (Callanan & Oakes, 1992; Callanan, Shrager, & Moore, 1995; Callanan & Jipson, 2001) have shown that parents seldom seek specifically to introduce complex scientific principles to young children, but they generally do respond sensitively to children's curiosity questions, sharing "factoids" as necessary (Crowley, Callanan, Jipson, et al., 2001). Parents frequently link scientific concepts to familiar examples (although sometimes inaccurately) and follow their child's lead in discussing complex scientific ideas. These opportunities and conversations may be the foundation upon which science interest grows.

Attempts to measure informal science–learning opportunities have come mostly out of two literatures—one from museums and the second from surveys of broader family-based activities. Museum-based analyses of parent–child conversations on topics related to science have generated a wealth of data concerning how children might construct knowledge related to science from interactions about particular topics or exhibits at zoos, museums, or nature parks (e.g., Callanan & Jipson, 2001; Crowley, Callanan, Jipson, et al., 2001; Crowley, Callanan, Tenenbaum, & Allen, 2001; Crowley & Galco, 2001; Falk & Dierking, 2000; Tenenbaum et al., 2005). This work has shown that families engage with exhibits in predictable ways, with parents frequently taking on the role of teacher in conveying exhibit information to young children (Ellenbogen, 2002; Hilke, 1989). Occasional gender differences have been found in the thoroughness with which parents introduce scientific topics within informal learning environments, with boys receiving more complete scientific explanations than girls (Crowley, Callanan, Tenenbaum, et al., 2001). Although the data from museum studies are rich in many ways, these studies typically have examined families cross sectionally at a single point in time and have tended to concentrate on parent–child or family interactions related to only one exhibit, limiting the conclusions we can draw in general about the influence of science-related learning opportunities on science interest or learning.

Alternatively, interviews with parents have been used to assess the broad range of informal science–learning opportunities within families, taking into account the breadth of exposure to science-related experiences within a child's home and community. Korpan et al. (1997) developed a semistructured interview entitled the Community and Home Activities Related to Technology and Science (CHARTS). Five sets of questions were created based on the emergent literacy and informal science–learning literature and were designed to determine the range and frequency of science-related activities in the home and community. Initial data were gathered from mothers of 25 kindergartners and 35 fifth- and sixth-grade children from Edmonton, Canada. Parents reported that their children, on average, engaged in reading about science and viewing television programs about science approximately 150 times per year for each activity domain. In addition, children engaged in approximately 12 community-based activities related to science per year on average, with some parents reporting weekly activities or outings related to science. Gender differences in opportunities were not reported.

Other large surveys of science-related opportunities have been replete with findings of gender differences. Kahle and Lakes (1983) reported that boys are more likely to have visited science-related places in the community (e.g., weather stations), read more science-related articles, watched more science-related television, and to have completed more science projects at home. In addition, Jones, Howe, and Rua (2000) found that boys are more likely to have had prior experience with the physical sciences including activities involving microscopes, electric toys, and pulleys. Girls are more likely to have had experiences with natural and life sciences including such activities as bread making, gardening, and observations of birds.

Children's Interests Related to Science

Interest is both a psychological state and an individual predisposition. When a child is interested in an activity or topic, they show increased persistence, positive affective engagement, and the tendency to direct attention to the object/event of interest over and above other choices (Hidi & Renninger, 2006). When an interest is relatively enduring, it is termed an *individual interest* (Renninger, 1989, 2000). Previous investigations of young children's interests have illustrated that even children as young as 2 years of age can show an interest in a topic (e.g., Hidi & Ainley, 2002; Krapp & Fink, 1992; Renninger, 1992).

We believe that interests, once well developed, do represent a basis from which children choose to engage or not engage future activities within a domain or topic. But, interests are not just about the particular object (i.e., a person-object interest; Fink, 1994) being attended to at the present. Interests for children often are concentrated on a type of object (dinosaurs) but involve a multitude of activities related to that object (reading about dinosaurs, watching dinosaur specials on TV, playing through pretend scenarios with plastic dinosaurs, showing their parents how many new things they learned about dinosaurs today). Interests and their related activities satisfy both a cognitive curiosity and provide an affectively positive experience. As we explore more fully below, however, interests do not develop in a vacuum (cf., Hidi & Renninger, 2006; Renninger & Hidi, 2011). Parents may significantly influence the persistence of early interests through the creation of contexts and environments in which particular kinds of interests develop and thrive.

Research is plentiful suggesting that children's interest in science-related topics varies by gender during early childhood and the elementary school years (Baram-Tsabari & Yarden, 2005; Folling-Albers & Hartinger, 1998; Maltese & Tai, 2011; Moller & Serbin, 1996; Schiefele, 2001; Weinraub et al., 1984). These differences persist into high school (Christidou, 2006; Buccheri, Gürber, & Brühwiler, 2011) and affect the likelihood of obtaining a degree in science (Tai, Liu, Maltese, & Fan, 2006). Studies have repeatedly shown that boys are more interested in studying science-related material than girls (e.g., Ford, Brickhouse, Lottero-Perdue, & Kilttleson, 2006; Keeves & Kotte, 1992; Kotte, 1992). Girls' more negative attitudes remain even in cases where they exhibit higher science grades and report greater interest in school and learning in general compared to boys (Catsambis, 1995; Keeves & Kotte, 1992). Baram-Tsabari, Sethi, Bry, and Yarden (2006) found that even some topics within science are seen as gender specific. Boys were more likely to ask spontaneous questions about physics, whereas girls asked more questions about biology. Farenga and Joyce (1999) found that physical science and technology-related courses were perceived to be appropriate for boys, whereas life sciences courses were perceived as appropriate for girls. These perceptions emerged years before the children would actually have the opportunity to take the offered courses in school.

Recently, a report from the National Research Council by Fenichel and Schwingruber (2010) and an article by Falk and Dierking (2010) have argued that informal science learning may be the key to increasing interest and achievement in science-related fields, particularly for girls. Gender differences in science-related interests are important to understand because the proportion of females and males entering science and engineering majors still varies significantly (National Science Board, 2006). In addition, interest has been found to correlate with indicators of learning such as elaborations and correct responses to comprehension questions as well as more global indicators such as increased domain knowledge, grades, and achievement (Maltese & Tai, 2010; Renninger, 2000; Schiefele, 1998; Schiefele & Krapp, 1996).

A Model of Coregulation for Interest Development in Early and Middle Childhood

Little research is available concerning the reasons why certain interests emerge and are sustained, whereas other interests diminish over time, or fail to develop at all. We believe it is unlikely that even relatively intense individual interests in preschoolers will culminate in considerable persistence and eventual knowledge gain without a substantial degree of support. Parents exert enormous control over very young children's environments by selecting, encouraging, or forbidding particular toys, books, and activities (Bradley & Caldwell, 1995; Chak, 2010). Furthermore, parenting styles can have substantial effects on children's play styles and interests (Creasey, Jarvis, & Berk, 1998; Pingree, Hawkins, & Botta, 2000). Whether parent-created opportunities spark child interest or child interest drives parent-provided opportunities is currently not well understood. We see three alternative models for this relationship over time.

First, the opportunities that parents provide in the home to learn about science may serve as natural triggers for interests related to science. Bronfenbrenner (1993) argues that development in general is an interaction between personal characteristics and important people with which the child interacts as well as the physical and symbolic features of settings in which the child finds him/herself. In addition, as Bronfenbrenner (1995) notes, the influence of the environment on the child is likely to be strongest when "participation occurs on a regular basis over an extended period of time" (p. 620). One could imagine a situation where parents (with their own beliefs and ideas about science) purchase particular toys or themselves enjoy particular venues to which they are more likely to take their children on a regular basis. The parent may also purposefully or accidentally model curiosity and exploration in particular topics or domains (Bradbard & Endsley, 1980; Chak, 2010). This environment of parental beliefs and opportunities becomes the foundation from which particular interests and curiosities of the child may evolve.

Second, the child's expression of a science interest could be noticed by family members first and subsequently lead to the provision of an increased number of opportunities to nurture that interest in science. In other words, parents use their child's interests to add new activities and opportunities to their child's repertoire with the express intent to grow the child's burgeoning interest and supply activities or resources that they know the child will enjoy.

Finally, a coregulation model may characterize interest development during childhood, with early experiences and opportunities facilitating interests related to science, and interests synergistically driving subsequent opportunities to engage further with learning about science. Our hypothesized coregulation model is similar to those found in other domains in which adults shape children's responses that ultimately come back to shape the parents (Eisenberg et al., 1999 in parenting/aggression; McDevitt & Chaffee, 2002; McDevitt & Ostrowski, 2009 in political activism; Chak, 2010 in children's exploratory behaviors).

Previous work on the development of conceptual interests (many of which are science related) suggests such a coregulation model. Johnson, Alexander, Spencer, Leibham, and Neitzel (2004) illustrated that parental beliefs in the importance of education and communication within the family, along with beliefs about the importance of consistency and time for play seem to "lay the groundwork" for conceptual interest development. Work by Leibham, Alexander, Johnson, Neitzel, and Reis-Henrie (2005) suggests, on the other hand, that parents provide support and opportunities after their child has expressed an interest in an area, keying off their child's specific history of engagement with the area of interest. The current study seeks to explore this relationship longitudinally.

Overview of Design and Hypotheses

The present study longitudinally examined the relation between early science–related opportunities provided in the home and the occurrence of science-related interests between the ages of 4 and 7 years. We hypothesize that children's developing interest in science emerges over time through coregulation between children's interest and the informal science opportunities parents provide. Second, we suggest that this coregulation cycle may differ for boys and girls and this may ultimately account for some of the gender differences in science interest.

METHOD

Participants

Our initial sample of participants included 215 children (90 girls, 125 boys) between the age of 4;0 and 4;6 when the study began ($M = 4;2$). These children were recruited for a prospective longitudinal study on interest development in young children (Alexander, Johnson, Leibham, & Kelley, 2008; Johnson et al., 2004; Leibham et al., 2005; Neitzel, Alexander, & Johnson, 2008). Families with 4-year-olds were recruited during a 12-month period during 1999–2000 through brief articles placed in local newspapers, flyers posted in pediatricians' offices, and a local children's museum, through university and community Listservs, and through preschools and daycares serving ethnically and socioeconomically diverse communities. In these communications, parents were informed only that the study was focused on exploring the types of play interests developed by preschool boys and girls and that children would receive small gifts in return for their participation.

Recruitment and testing were based at two sites: an urban university campus (77% of the sample) and a rural university town within the same midwestern state. Attrition due to moves out of state or to changes in family schedules reduced the number of children seen during the 3 years of the study. Thus, analyses are based on $N = 215$ at 4–5 years of age, $N = 199$ at 5–6 years of age, and $N = 192$ at 6–7 years of age. The 12-month recruitment window permitted staggered assessments throughout the study.[1]

The majority of the sample (86%) was Caucasian, with 6% African American, 3% Hispanic/Latino, and very small percentages of Asian and Native American children. The median income bracket of participating families was between \$55,000 and \$65,000 ($SD =$ \$35,000), and the mean level of education for both mothers and fathers was approximately 16 years. At the time of recruitment, 61% of the sample was reported to be first born and 20% of the sample had no siblings whereas 57% had one sibling. On average, the children spent 19.59 hours in nonhome care at age 4 years ($SD = 17.06$ hours). Across contacts for the 36 months, most parent respondents were mothers (93%).

Measures

Opportunities for Informal Science Learning. Dierking and Martin (1997) define informal learning opportunities as "nonsequential, self-pacing, nonassessed, and often involving groups" (p. 629). For the present study, we operationalized informal science–learning opportunities as community and home activities that might inform children's growing conceptions about science and scientists and that were designed at a minimum to expose the child to science-related content. Although science can be incorporated into many informal activities (e.g., discussions in an art museum about the aging of a manuscript), science-specific activities represent consistent opportunities for students to be exposed to science-related ideas and facts. We were interested in activities in the community (e.g., science museum visits), activities in the home (science experiments, others with science-related hobbies), TV watching, reading, and, at older ages, computer use related to science. For us, frequent exposure to these types of activities should translate to more opportunities for science-related conversations and learning to occur as well as opportunities to pique curiosity about science-related topics.

During laboratory visits when children were 4 years old and again at age 5, parents completed a questionnaire that included 14 items focused on the frequency of family activities related to science. The age 4 items (along with point values used to quantify parents' responses conditional on gender) are available in Table 1. Scores were summed and then standardized at each age yielding the age 4 and age 5 Science-Learning Opportunity (SLO) indices.

When children were 6 years old, we asked parents to complete items from the Community and Home Activities Related to Science/Preschool (CHARTS/PS; Korpan et al. 1997; Korpan, Bisanz, Bisanz, & Lynch, 1998) that were similar to questions asked at ages 4 and 5 but asked for more extensive detail about the science-related activities. Particular items (e.g., lists of science-related television shows, community activities) were adapted to reflect locally available opportunities for science learning. Scores for items were summed and then

[1] Although 89% of the sample was retained across the 3 years of the study, it is important to point out that the voluntary nature of families' participation could ultimately limit the generalizability of findings. Parents (and children) were willing to participate in repeated assessments and to be telephoned (or e-mailed) multiple times per year for monitoring of children's interests. We thus have a sample that is likely to include a disproportionately high representation of relatively stable families with few socioeconomic or psychosocial stressors.

TABLE 1
Items Assessing Science-Learning Opportunities: Age 4

Item	Number of Points Assigned	Boys: *M* (*SD*)	Girls: *M* (*SD*)
Frequency of activities			
Has your child attended a science museum in the last year?	1	0.73 (0.45)	0.70 (0.46)
Has your child attended a zoo/aquarium/botanical garden in the last year?	1	0.92 (0.28)	0.91 (0.30)
How often do you visit the zoo or aquariums (greater than 8 times per year = 4 points; less than once a year = 1 point; never = 0 points)	0–4	2.64 (.89)	2.62 (0.89)
Do you, your spouse, an older sibling, or frequent playmate have the following hobbies?			
Modeling (e.g., cars, trains airplanes)	1 for each person, 0–4	0.27 (0.52)	0.21 (0.49)$^{+}$
Birdwatching	1 for each person, 0–4	0.26 (0.60)	0.31 (0.71)
Computers (separate from gaming)	1 for each person, 0–4	1.77 (1.12)	1.65 (1.02)
Animals (specify animal)	1 for each person, 0–4	0.73 (1.15)	0.88 (1.02)
Science	1 for each person, 0–4	0.68 (0.96)	0.58 (0.79)
Gardening	1 for each person, 0–4	0.97 (0.87)	1.05 (0.89)
Paleontology (e.g., dinosaurs, fossils)	1 for each person, 0–4	0.52 (0.82)	0.33 (0.89)$^{+}$
Electronics	1 for each person, 0–4	0.41 (0.56)	0.37 (0.53)$^{+}$
Outside of school, how often does your child watch the following TV or video programs?			
Nature, wildlife, or history (7 points = daily, 1 point = weekly)	0–7	1.57 (2.32)	1.38 (2.34)
Outside of school, how often does your child read or have read the following books?			
Nature, wildlife (7 points = daily, 1 point weekly)	0–7	2.04 (2.63)	1.55 (2.27)
How things work (7 points = daily 1 point = weekly)	0–7	1.36 (2.09)	0.70 (1.47)$^{*+}$
Total possible range	0–35	15.10 (7.12)	13.75 (5.33)

*Age 4, $t(203) = 2.5$, $p < .05$.
$^{+}$Age 5, $t(200) > 1.97$, $p < .05$

standardized to yield the age 6 SLO index. Relevant items, point values, and summaries of responses broken out by child's gender are presented in Table 2.[2]

To control for natural variations among families in terms of the frequency with which they tend to engage in activities in general outside of the home, a family activity score was calculated. At ages 4 and 5, items related to frequency of non–science-related activities such as art museum visits, musical events, movies, and theater visits were coded using scales modeled after those used for science-related activities (see the Appendix). These items were summed to create a family activity score for each age. At age 6, similar nonscience community-based activity items (including assessments of the frequency of visits to amusement parks and attending meetings of groups such as scouting events) were coded and summed to create a family activity score for age 6 (see the Appendix). The three family activity scores were later averaged to provide a covariate measure for some (though not all) of the analyses.

Interests Related to Science. For the present study, we were interested in capturing individual rather than situational interests (Hidi & Renninger, 2006). We operationalized children's interests through parent answers to three questions: (1) What does your child prefer to do during free play time?, (2) If your child had one hour to do anything, what would they prefer to do?, and (3) Does your child seem to have a focused interest (and what is it in)?

Interest reports were later coded as science or nonscience related. If answers to any of the three questions identified an interest related to science, children were credited with a science interest during that contact. Science interests were defined as those aligned with the content areas of the CHARTS, including life science and nature (e.g., dinosaurs, horses), earth science (e.g., rocks, space), mechanics (e.g., cars), or technology (e.g., computers). When the science orientation of a particular interest domain was ambiguous, the nature of the child's activities when engaged with the domain was evaluated. For example, a child interested in horses who was engaged only in horseback riding would *not* be credited with a life science interest, whereas a child interested in horses who read extensively about different kinds of horses and who collected horse models in addition to her horseback riding *would* receive life science credit. "Computers" was considered a science-oriented interest only if the child expressed interest in how the computer or Internet worked; no credit was granted if the child was simply interested in using the computer to engage in games or learning activities.

Coding was performed by a single author, with a second author recoding the interests for 20% of the sample. Raw agreement between the two coders was 97%, and the few disagreements were resolved through discussion between the two authors.

[2] In the initial development of the CHARTS/PS questionnaire (Korpan et al., 1998), no factor analysis was presented. We did submit data collected when children were 6 years old to a principal axis factor analysis with varimax rotation (there were too few items administered in year 1 to conduct a parallel factor analysis on the items listed in Table 1). The analysis revealed five discrete factors (with 20 of the 24 items loading cleanly on the five factors). However, the intercorrelations among the factors were quite high ($r =$ .21 – .50, ps $< .001$), suggesting an underlying conceptual coherence. Gender differences emerged for two factors: (1) boys were reported to spend more time engaged in science-related activities (including TV viewing and reading) and to ask higher percentages of questions related to science; $t(191) = 3.6$, $p <$ .001; (2) parents of boys also were more likely to respond to their child's questions by gathering additional information; $t(191) = 2.2$, $p < .05$. These factor differences largely reflect individual item differences already reported in Table 2. Because we were interested in estimating the total opportunities for science learning in the home, we decided to retain the composite SLO index rather than estimating factors for subsequent analyses of relations with children's science interests.

TABLE 2
Items Assessing SLO from CHARTS/PS: Age 6

Item	Number of Points Assigned	Boys: *M* (*SD*)	Girls: *M* (*SD*)
Percent of time devoted to science, nature or technology?			
Reading (0–20% = 1, 80–100% = 5)	1–5	2.24 (1.12)	1.58 (0.97)*
Computer Time (0–20% = 1, 80–100% = 5)	1–5	1.63 (1.05)	1.23 (0.55)*
TV (0–20% = 1, 80–100% = 5)	1–5	1.65 (0.93)	1.47 (0.88)*
How many times has someone conducted science experiments with your child in the last year?	Frequency	5.72 (7.75)	4.98 (9.02)
What proportion of your child's questions are related to science? (1 = no question; 2 = rarely; 3 = some questions; 4 = 75% or more of questions)	0–4	3.11 (0.85)	3.05 (0.76)
How often do the following activities inspire science related questions from your child (1 = rare, 2 = some, 3 = most of the time; 4 = every time)			
Participating in hobbies or activities related to science	0–4	2.44 (1.22)	2.46 (1.13)
Reading a book on science	0–4	1.96 (1.47)	1.86 (1.33)
Using a computer	0–4	1.95 (1.22)	2.00 (1.26)
Watching a TV program on science	0–4	2.51 (1.24)	2.47 (1.14)
Taking care of animals or gardening	0–4	2.12 (1.20)	2.56 (1.02)*
Attending a community activity or program	0–4	1.36 (1.55)	1.18 (1.50)
Watching a movie or video on science	0–4	2.14 (1.46)	1.95 (1.32)
When answering science related questions how likely are you to do the following? (1 = never, 3 = some of the time, 5 = always)			
Consult an encyclopedia	0–5	2.06 (0.92)	1.86 (0.96)
Consult a science-related book	0–5	2.64 (0.92)	2.51 (0.95)
View a movie or video	0–5	2.17 (0.91)	1.86 (0.88)*
Ask someone who may know the topic	0–5	2.92 (0.85)	2.72 (0.91)
Make a careful observation or conduct a simple science experiment	0–5	2.35 (0.86)	2.46 (0.81)
Search the Internet	0–5	2.60 (1.05)	2.60 (0.96)

(*Continued*)

TABLE 2
Continued

Item	Number of Points Assigned	Boys: *M* (*SD*)	Girls: *M* (*SD*)
How comfortable do you feel answering your child's science-related questions? (1 = very uncomfortable, 5 = very comfortable)	0–5	4.17 (0.98)	4.30 (0.84)
Does your job (or alternate adult in house) involve science? (1 point each, max 2)	0–2	1.19 (0.79)	0.98 (0.80)
How interested are you in science? (1 = very uninterested, 5 = very interested)	0–5	4.09 (0.97)	1.07 (1.00)
How many hours per month are spent watching specific science-related TV shows?			
Number of different kinds of science shows watched	Raw range	4.52 (2.53)	3.81 (2.34)*
Number of hours spent watching science shows per month	Raw range	10.67 (12.53)	9.79 (11.42)
How frequent are visits to specific science-related community activities over last year?			
Number of different kinds of science activities	Raw range	4.71 (2.26)	4.58 (2.00)
Total number of science activities	Raw range	13.75 (10.23)	12.69 (10.23)
Total possible range	0–161	72.75 (28.17)	68.90 (24.10)

*$t(190) > 1.97$, $p < .05$.

Procedure and Design

Each parent completed activity-related questionnaires, whereas his/her child participated in unrelated annual laboratory assessments. After the first year, a small number of annual assessments were conducted as home visits when parents had difficulty traveling to the laboratory. Data about children's interests were gathered beginning at age 4 years through bimonthly telephone or e-mail contacts (six per year). To reduce the burden on families following the transition to school, contacts were made once every 4 months when children were between ages 6 and 7 years. Telephone interviews typically took between 7 and 10 minutes to complete. Not every child had interest data at each of the contact points because of scheduling difficulties. Parent–child dyads were included in the longitudinal analyses if they completed at least five of six interviews during each 1-year interval between ages 4 and 5 and ages 5 and 6 as well as at least two of three interviews between ages 6 and 7 years. To deal with variations in the number of interviews, child interest was represented by the proportion of contacts in which a science interest was reported across each year.

Our design was prospective longitudinal, and our analytic strategy was necessarily correlational. It would have been impossible to group (or assign) families to conditions that would control for opportunities to engage in informal science learning, and it was impossible to determine at the outset which children would manifest fleeting or sustained individual interests related to science. Although this makes it impossible to derive causal inferences concerning the relationship between science interests and opportunities, we statistically controlled theoretically relevant variables when possible and employed multiple group path analyses to examine relations between these constructs over time.

RESULTS

We first provide descriptive information exploring gender differences in opportunities for science activities and science interests at ages 4, 5, and 6. Next, using multiple group longitudinal path analyses, we test our hypothesis that children's developing interest in science emerges through a coregulation cycle between children's interest in science and the opportunities parents provide for informal exploration of science.

Initial analyses revealed no significant differences in frequency of reported science interests by birth order (first vs. all others; all ts < 1.5, ns), number of siblings (0 vs. all others; 0 and 1 vs. all others; ts < 1.01), or number of hours in out-of-home care (median split at each year (ts < 1.6). As a consequence, these variables were discarded from additional analyses.

Opportunities for Science Learning

SLO scores at each age (4, 5, and 6) were compared via a repeated measures analysis of variance (ANOVA) with age at testing as the within-group factor and gender as the between-groups factor. The means and standard errors associated with this analysis are presented in the top row of Table 3. Results indicated no significant effect of gender, $F(1, 190) = 3.50$, *ns*, $\eta_p^2 = 0.02$; suggesting that relative levels of experience with informal science opportunities were not statistically different between genders. To control for natural variations among families in terms of the frequency with which they tend to engage in activities in general outside of the home, this analysis was rerun as an analysis of covariance (ANCOVA) with the average family activity score covaried out. Results indicated that the family activity score was significantly related to SLO scores indicating that it was a good covariate, $F(1, 189) = 37.53$, $p < .001$, $\eta_p^2 = 0.17$. In addition, the effect of gender on SLO scores

TABLE 3
Means and Standard Deviations for All Standardized Variables Included in Path Analysis, Reported by Gender

Measure	Boys: *M* (*SD*)	Girls: *M* (*SD*)
Science-Learning Opportunity (SLO) score (standardized)		
Age 4	0.10 (1.11)	−0.12 (0.83)
Age 5	0.13 (1.09)	−0.19 (0.83)
Age 6	0.06 (1.07)	−0.10 (0.89)
Science interests (proportion of contacts)		
Age 4	0.47 (0.38)	0.16 (0.27)
Age 5	0.36 (0.39)	0.12 (0.24)
Age 6	0.27 (0.38)	0.11 (0.26)
Non−science -related activities (standardized)		
Age 4	−0.08 (0.97)	0.07 (0.98)
Age 5	−0.09 (1.04)	0.13 (0.93)
Age 6	−0.11 (0.88)	0.15 (1.13)

Boys: $n = 125$, 117, 111 ages 4, 5, and 6, respectively.
Girls $n = 90$, 82, 81 ages 4, 5, and 6, respectively.

was now significant, $F(1, 189) = 7.51$, $p < .01$, $\eta_p^2 = 0.04$ with parents of boys reporting more science-related opportunities than parents of girls.

With the exception of only one item pertaining to caring for animals, items yielded differences in science-learning opportunities that were in favor of boys. The majority of these items pertained to the frequency with which children interacted with science-oriented sources of information (books, digital media). Although no significant gender difference in the total number of reported hours spent watching science content on TV was found at age 6, boys tended to view a wider *range* of science-related TV programs than girls, $t\ (191) = 2.06$, $p < .05$, $d = 0.30$. Boys and girls were reported to initiate simple experiments and observations at comparable rates (see Tables 1 and 2 for details).

Children's Science Interests

We identified children as interested in science if their parents reported a science-oriented activity for any of the three target questions during each phone contact. This frequency count was then converted to a proportion of contacts in which science interests were reported. A repeated measures ANOVA with time as the within factor and gender as the between factor found significant main effects for gender, $F(1, 199) = 30.41$, $p < .001$, $\eta_p^2 = 0.13$ and time, $F(2, 398) = 21.34$, $p < .001$, $\eta_p^2 = 0.10$, as well as a significant interaction of gender and time, $F(2, 398) = 9.54$, $p < .001$, $\eta_p^2 = 0.05$ on proportion of contacts in which science interests were reported (see means in Table 3). Boys were more likely than girls to be identified as having science interests. In addition, proportion of contacts in which science interests were reported declined significantly throughout the period of the study.

To explore the interaction more fully, repeated measures ANOVA for each gender were conducted. Results revealed significant time effects for boys, $F(2, 232) = 27.71$, $p < .001$, $\eta_p^2 = 0.19$ with proportion of contacts in which science was reported as an interest decreasing significantly over time. Proportion of contacts in which science was reported as an interest did not decline significantly for girls, $F(2, 166) = 1.70$, *ns*, $\eta_p^2 = 0.02$, but did remain quite small across all three time periods. Figure 1 illustrates the trends over time.

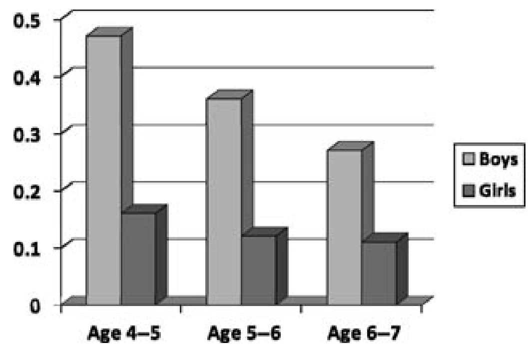

Figure 1. Proportion of contacts in which science was reported as an interest each year by gender.

Relation Between Opportunities for Science Learning and Science Interests

The critical question driving our investigation was the degree to which children's science interests were related to parents' reports of opportunities for informal science learning in the home and local community, and whether this relation differed for boys versus girls across time. Initial exploration of relations between SLO and nonscience family activity scores (reflecting general tendencies to engage in family activities outside of the home) at each age revealed significant correlations (r [214] = .36 at age 4, r [206] = .33 at age 5, and r[193] = .20 at age 6, ps < .01), suggesting a general tendency for some families to engage in both science and nonscience activities more often than other families. To control for these differences, non–science-related activity scores were included in the path analyses reported below.

A multiple group (gender) path analysis model was used to examine the relationship between science-related interests and science-related opportunities across the three measurement occasions. In contrast to simpler methods, the advantage of a path analysis model is that path analysis maps a theoretical model onto the variables and allows for overall fit of the model to be evaluated as well as quantifying the relation among the variables connected by paths. The path analysis model and the corresponding maximum likelihood parameter estimates are depicted in Figure 2. Means and standard deviations for all variables are shown in Table 3.

Using measures of science interests (ages 4–5, 5–6, and 6–7) and measures of science-related opportunities that parents reported at ages 4, 5, and 6, we modeled the effect of all later scores conditional on their previous values (i.e., the autoregressive effects) as well as the influence of the scores conditional on the previous value of the other measure (i.e., the cross-lagged effects). We also included non–science-related interests at each of the three time points as a control variable for both science-related interests and science-learning opportunities. Of primary interest are the cross loadings from science-related interests to science-learning opportunities in subsequent years and from each SLO to science-related interests in subsequent years.

As a way to quantify the overall model effectiveness, we used the root mean square error of approximation (RMSEA). An RMSEA less than 0.05 generally denotes close fit to the model, less than 0.08 a reasonable fit to the model, and anything greater than 0.10 as an ill fit to the model (Brown & Cudeck, 1992). The RMSEA of the fitted model was 0.077 with a corresponding 90% confidence interval limits of 0.040 and 0.110. Thus, the point estimate is in the reasonable range with the upper confidence interval limit slightly beyond

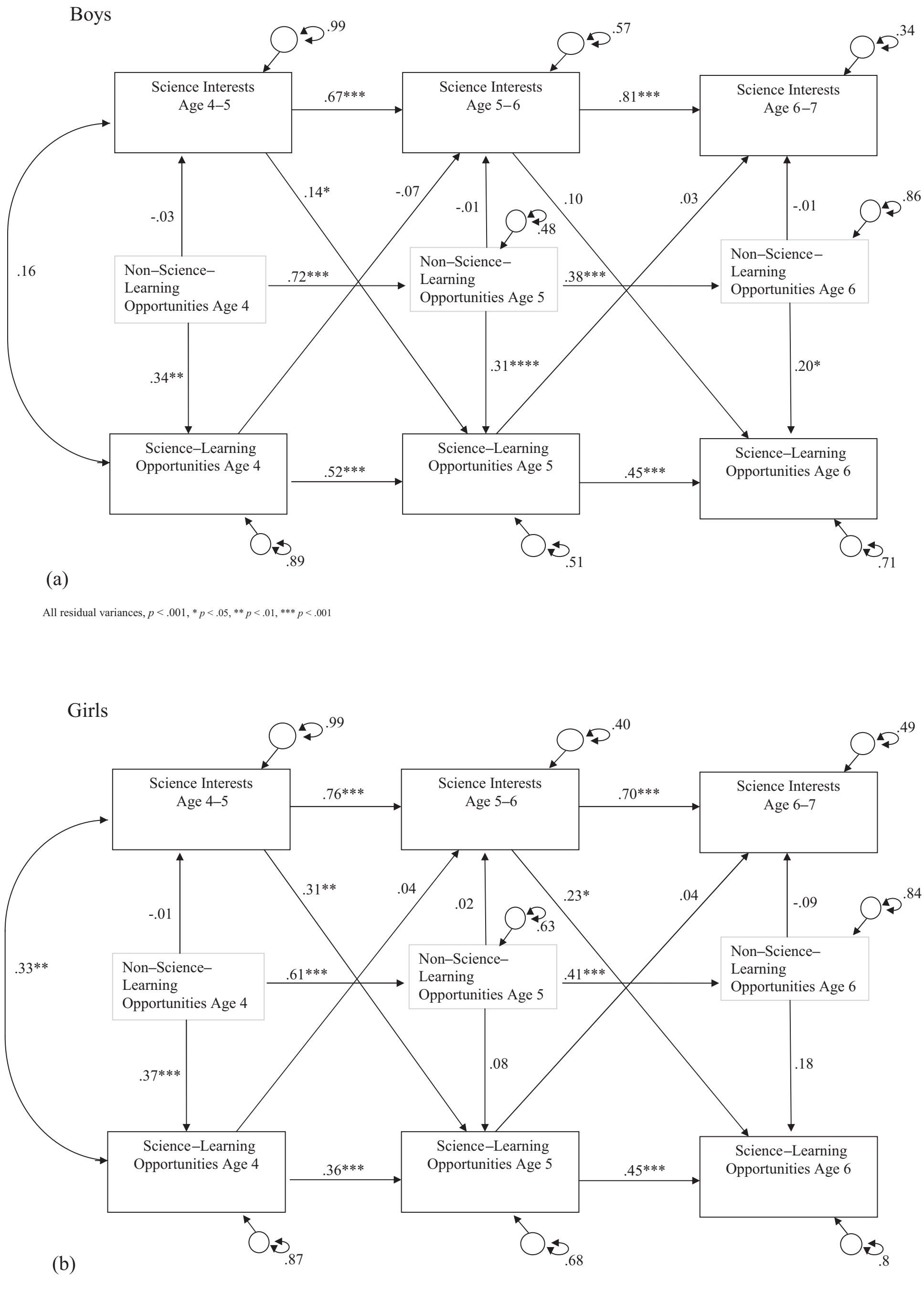

Figure 2. (a) Path analysis predicting future science-related interests and science-learning opportunities given age early science-related interests and science-learning opportunities for boys. (b) Path analysis predicting future science-related interests and science-learning opportunities given early science-related interests and science-learning opportunities for girls.

TABLE 4
Proportion of Variance Accounted for in the Path Analysis, Reported by Variable and Gender

Measure	Boys' Model	Girls' Model
Science-Learning Opportunity Score Age 4	0.11*	0.13 $^{p=.052}$
Science-Learning Opportunity Score Age 5	0.49***	0.32***
Science-Learning Opportunity Score Age 6	0.29***	0.20***
Proportion of Contacts with Interest in Science Age 4–5	0.001	0.000[a]
Proportion of Contacts with Interest in Science Age 5–6	0.43***	0.60***
Proportion of Contacts with Interest in Science Age 6–7	0.66***	0.51***
Nonscience Opportunity Score Age 5	0.52***	0.37***
Nonscience Opportunity Score Age 6	0.14*	0.16*

Overall model RMSEA 0.077, 90% confidence interval = 0.039, 0.110.
[a]Both of the Age 4 variables in the model were considered predictors of later variables. We did not attempt to explain variance in either of these variables. The significant outcome noted in this table for the Age 4 SLO Score is an artifact of the relation between that variable and the Age 4 Nonscience Opportunity Score (thus confirming the appropriateness of including Nonscience Opportunity Scores in the current analysis).
*$p < .05$, **$p < .01$, ***$p < .001$.

the acceptable range. Correspondingly, we regard the model as reasonable based on the RMSEA value.

Table 4 shows the proportion of variance accounted for in each of the variables in the model (all but nonscience interests at time 1). A significant amount of variance in each of the variables is being explained by the predictors included in the model. More interestingly, however, the path analysis evidence suggests that both boys' and girls' early science interests are responded to positively by parents with an increase in the provision of additional science-learning opportunities the year following the reported interest. The pattern is more robust for girls and can be seen across all three time points we captured. Within the timeframe of our study, we were unable to document a longitudinal relationship between the provision of early science opportunities and later development of science-related interests.

Science-Learning Opportunities Details

Given the significant effects of interest on later science-learning opportunities, we explored differences in opportunities available for girls who expressed high versus low levels of science interest at age 4 (girls with no reported interests in science from ages 4–5, vs. girls whose proportion of contacts with a science interest was at least 0.17). At age 4, few differences emerged between girls classified in these groups. Girls with higher levels of science interest resided in homes with other people who shared science-related hobbies including birding, animals, and science in general (all t (82) > 1.97, $p < .05$). There were, however, no differences in reported frequencies of reading books related to science or watching science-related TV.

At ages 6–7, girls high in science interest at age 4 now spent a higher proportion of their reading and TV time devoted to science than girls with no science interests at age 4. They were also reported to watch more hours of TV related to science. The number of science-related community activities did not differ between girls with no science interests at age 4 and those with science interests. Both reading and TV watching were reported to be more likely to inspire science-related questions from girls with science interests than from girls with no science interests at age 4. Interestingly, parents of girls with science interests reported being significantly more interested in science themselves than parents of girls with no science interest at age 4. Finally, parents were less likely to consult the Internet to answer their daughters' science question (preferring books or encyclopedias instead) if their daughter had an interest in science at age 4 than if they had no interest in science. Table 5 details these significant findings at ages 6–7.

DISCUSSION

Not surprisingly, we found that during the period from preschool to middle childhood, earlier interests in science are the best predictors of later interests in science, and early informal science-learning opportunities predict later opportunities to engage in science-related activities for both boys and girls. It is noteworthy that these patterns emerge in children so young. Some have argued that stability of interests over time is very low in children younger than age 12 (Low, Yoon, Roberts, & Rounds, 2005). Others have found that interests do show moderate levels of stability during the late elementary school years (Tracey, 2002; Tracey & Sodano, 2008; Tracey & Ward, 1998). Our data reveal that this stability may be evident much earlier than previous studies have demonstrated.

The stability and individual specificity of these young children's interests also prompts a reexamination of Todt and Schreiber's (1998) assertion that early interests are simply reflective of the sequence of cognitive development (e.g., Piagetian structures). We agree that there is likely a limited range of interests available to young children simply because of what is cognitively available to them. We would not expect a young child to develop an interest in aeronautical engineering. They do, however, want to figure out how to get their paper airplanes to fly further and their Lego-built wings to become longer on their Lego-built airplane. Thus, to some extent, Todt and Schreiber (1998) are correct in that there is a limit to the possibilities young children express in terms of interests. The specificity of the interests and length of engagement suggest, however, that these are "real" individual interests and are in the process of at least becoming aspects of the way the self is viewed (see individual interest growth models by Krapp, 2002, and Hidi & Renninger, 2006, for similar views).

In the present study, there was a similar stability from year to year in the frequency of science-related opportunities provided by the parents. This suggests that the middle-class families in our study established routines very early on in children's lives and were apt to continue those same routines for a significant period of time. The most significant discovery that emerged from our analysis was that early science interests expressed by children were strong predictors of later opportunities to engage in informal science learning, whereas the opposite pattern (early opportunities predicting later science interests) was not found.

Our results indicate fairly typical gender differences in parents' reports of children's interests related to science domains. There were, however, effects of gender that are noteworthy. For example, our results suggest that when young girls exhibited science interests, parents were particularly prone to provide more opportunities for science learning later on in childhood. This was also true for the boys in our sample, though the pattern of support became less strong over time. In fact, our data suggest that boys received science opportunities regardless of their expressed interest in science after the age of 4. Girls, on the other hand, received a greater number of science opportunities when they expressed an interest in science than when they did not. This support includes reading and watching TV related to science, responding to science-related questions connected to that reading and TV viewing,

TABLE 5
Differences in Specific Science-Learning Opportunities for Girls with Low and High Interest in Science at Age 4

Item	Number of Points Assigned	Low Interest Girls: *M* (*SD*)	High Interest Girls: *M* (*SD*)
Percent of time devoted to science, nature or technology?			
Reading (0–20% = 1, 80-1-00% = 5)	1–5	1.33 (0.77)	2.00 (1.14)$^{+}$
TV (0–20% = 1, 80–100% = 5)	1–5	1.24 (0.51)	1.87 (1.19)$^{+}$
How often do the following activities inspire science related questions from your child (1 = rare, 2 = some, 3 = most of the time; 4 = every time)			
Reading a book on science	0–4	1.55 (129)	2.40 (1.25)$^{+}$
Watching a TV program on science	0–4	2.24 (1.19)	2.87 (0.94)$^{+}$
When answering science related questions how likely are you to do the following? (1 = never, 3 = some of the time, 5 = always)			
Search the Internet	0–5	2.76 (0.86)	2.33 (1.06)*
How interested are you in science? (1 = very uninterested, 5 = very interested)	0–5	3.90 (1.06)	4.40 (0.81)*
How many hours per month are spent watching specific science-related TV shows?			
Number of hours spent watching science shows per month	Raw range	6.22 (4.89)	15.84 (15.64)$^{+}$
Number of different kinds of science shows watched	Raw range	3.31 (2.03)	4.66 (2.48)$^{+}$
Total number of science activities	Raw range	12.19 (7.78)	13.54 (13.12)^{NS}

$^{*}t(79) > 2.00$, $p < .05$.
$^{+}t(79) > 2.48$, $p = < .01$.

and consulting reliable sources to help respond to children's questions.[3] Differences in frequency of community-based science-related activities were not found.

Interestingly, our results showed no direct effect of early opportunities for science learning provided in the home on children's subsequent expression of science-related interests for either gender, at least between the ages of 4 and 7 years. This absence of a relation is surprising and runs counter to many middle-class parents' beliefs about the importance of supplying early quality science-related experiences to young children. Our data clearly show that many children were already interested in science-related domains at age 4. It seems possible that in some families, parents' provision of science-related opportunities may have effects on the development of children's early interests *prior* to age 4. Retrospective reports from parents in the present study confirm that the early emergence of interests was clear, occasionally as early as age 18 months. Parents also, at age 4, reported that their child had been interested in their science-related topic for an average of 18 months when we interviewed them with age of first interest commonly reported between 2 and 3 years of age. Thus, it is quite possible that parents' early provision of science-related activities piqued interests in their toddlers, but our timeframe for data collection limits the conclusions we can draw.

Regardless of how or how frequently early science–related activities occurred, it is important to recognize the fallacy behind the idea that interest comes from simply putting activities in front of children. The Coregulation Model of Interest Development suggests, similar to Renninger and Hidi's (2011) Four Phase Model of Interest Development, which interests are more likely to develop in an environment with external support from parents. It cannot be simply a case of involving children in science and expecting that they will consistently come to subjectively value science.

If putting science in front of children is not enough to spark an interest, do we have hints about what might facilitate the triggering of an interest? Krapp and Prenzel (2011) and Maltese and Tai (2010) have suggested that quality of instruction may make a difference in interest development, particularly for girls. Our findings suggest that children's interests did not develop in isolation and were likely supported by a parent with the ability to answer domain-related questions. In Johnson et al. (2004), we noted that 69% of children who displayed one particular kind of interests (conceptual interests; dinosaurs, trains) at age 4 had another family member who shared the same or a related interest (e.g., a father interested in collecting baseball cards residing with a child passionate about collecting Pokémon cards; a child interested in dinosaurs living with a mother who reluctantly admitted that she had always been interested in dinosaurs as a child but had never told her son directly).

Children also need to have time to engage in the kinds of science-related activities that they enjoy, feel competent doing, and during which they experience affective reactions like flow (Csikszentmihalyi, 1990; Prenzel, 1992). Our early explorations of data from this cohort (Johnson et al., 2004) suggest that the development of conceptual interests was more likely when children resided in homes for which free play time was plentiful and an emphasis on communication was present. In other words, free play opportunities need to be accompanied by family discussions and the communication of ideas in order for such interests to flourish.

Our longitudinal data also suggest that some variables are unimportant in predicting science-related interests. For example, although it might seem plausible that individual

[3] At the time these data were collected (late 1999 to late 2002), the Internet was not well developed as a source of information. For example, *Wikipedia* launched in 2001 and, although its use grew steadily, it was not well developed enough to truly affect our parents' views about reliable resources on the Internet. Even the Internet itself was mainly online shopping and discussion blogs rather than the vibrant and fun source of games and information we have come to value in 2012.

difference variables such as birth order, number of siblings, and number of hours in out-of-home care affect the likelihood that an interest in science would develop, our data suggest otherwise. Birth order was not a significant predictor of science interests. Being an only child, or a child with only one sibling, was not associated with children manifesting a higher rate of science-related interests. Finally, the number of hours of out-of-home care was not related (either positively or negatively) to the likelihood of developing a science-related interest. This suggests that parents do not have to be available at every moment for a child to support a growing interest in science; they likely do need to be responsive when the opportunity arises.

The decline in children's reported science interests over the early and middle childhood years is somewhat troubling. Parents reported that boys' interests related to science declined significantly between the preschool years and early elementary school years, whereas girls' interests were reported to remain relatively low and stable. Although it is unclear why boys' interests tended to decline, parents frequently mentioned during our phone contacts that after first grade began, their child had considerably less free time in which to engage in play activities related to his interests. Many parents also reported that children became more sensitive to the particular interests of their peers and tended to align their play interests to activities preferred by same-sex peers, in particular. Future research clearly is needed to better understand the impact of school and peer influences on children's expressed interests and preferred play activities related to science.

In sum, our data support the hypothesized coregulation pattern only partially. Our results do mirror those found by other researchers (e.g., Palmquist & Crowley, 2007) confirming parents are sensitive and willing to support a detected interest. Indeed, many parents reported during our phone contacts that once relatives and friends were aware of the child's interest, additional toys and books related to the science topic were given to the child as gifts on birthdays and holidays. The strength of the pattern for girls is encouraging. This suggests that parents are aware of prevailing cultural stereotypes involving women and science, and these middle-class parents, at least, actively work against them by supporting budding science interests in their daughters.

In the larger picture, the root of gender differences in the overall proportion of boys' and girls' science-related interests is unclear. Both socialization and biologically determined differences have been suggested as causes by different researchers. Lytton and Romney (1991) conducted a meta-analysis of parents' socialization of boys and girls and reported that that the majority of effects associated with differential gender socialization were small or nonsignificant. However, the home environments of boys and girls differed significantly in terms of the degree to which parents encouraged sex stereotypes in play activities and household chores. It is unlikely, however, that parents would intentionally limit girls' opportunities to learn about science, particularly since there is relatively little stigma associated with girls' interests in male-typed activities (compared to boys with interests in feminine-typed activities; Fagot & Hagen, 1991; Jacklin, DiPietro, & Maccoby, 1984). Gender-typed toy preferences may contribute to some of these differences with boys gravitating toward objects such as dinosaur models, telescopes, and bug-collecting kits, which typically are male-typed items. Girls' sensitivity to the gender typing of such items may lead them to consider such objects to be personally undesirable (Moller & Serbin, 1996).

Additional implications of early gender-based differences in science interest can be drawn from the work of Crowley, Shaffer, and colleagues. Crowley and Jacobs (2002) have argued that the early support of learning by parents creates an island of expertise that assists children over time to build new knowledge. This island of expertise expands as the child's interest and knowledge grows. Shaffer (2006) proposes that involvement in a domain in meaningful ways helps a child see "that learning matters and that [the child] can be good at learning complex, technical, and specialized things" (p. 7). He also notes that extensive meaningful experience in a domain might cause a learner to experience shifts in "epistemic culture" or "frames" as he or she comes to see oneself as a member of a community who values the ways of thinking of that community. On the basis of Shaffer's framework, we propose that children exhibiting early science interests that are subsequently supported by their parents may begin to develop an identity as someone who sees things the same way scientists do. This shift in "frames" may be particularly important for young girls to encourage continued involvement in the domain.

A clear limitation in our design is our reliance on parental reporting of child interests. We chose not to ask children directly about their play interests because we were concerned that they would not be able to provide valid responses early on in childhood and could not be queried by phone at regular intervals. We assumed that children would have difficulty evaluating the degree to which their interests remained stable over time as their understanding of time concepts was developing throughout the period of the study. In addition, we believe the difficulty of querying young children to collect enough data to test our model was prohibitive. Yet parental reports of their children's interests are apt to be filtered by their own schemas and expectations (Martin, 1999), and parents may unintentionally (or intentionally) distort their characterization of their child's interest. Although these concerns cannot be completely allayed with our current data, relying on parent report and self-report about interests is common, and often retrospective (e.g., DeLoache, Simcock, & Macari, 2007; Ericsson & Crutcher, 1990). Our data are based on a short-time frame (last few weeks at each time of report) with repeated reports over time, and our questions were not specifically framed to examine gender differences in play interests, nor focused explicitly on science.

Conclusions and Implications

Although the establishment of definitive causal relations between science interests and opportunities for science learning is limited by the essentially correlational nature of the research and to some extent the questions we asked about science-related opportunities (derived from the CHARTS), our findings suggest that parents respond sensitively to children's science interests by intentionally creating contexts for exploration and learning of science concepts during the preschool and middle childhood years. These opportunities may prove pivotal to children's sustained expression of science interests over time. Interests that are sustained over time are hypothesized to be more likely to culminate in the development of basic knowledge, ideas, vocabulary, and "epistemic frames" that can later support learning from science texts and enhance science achievement. Thus, parents are poised to play a pivotal role in nurturing and shaping their child's interests in science for years to come. Noticing a child's interest in science, particularly a young daughter's, around the age of 4 seems a critical first step.

In addition, our findings suggest a pivotal resource that could be used to increase children's engagement with science, technology, engineering, and mathematics disciplines. We can assist parents (and early childhood educators) with recognizing a child's growing interest in science and then help them support it. This support may need to be provided in multiple ways to assist parents and teachers when responding to children's science-related questions. Although *Wikipedia* (launched in 2001) was not well developed during this study, there is now a wide array of Internet resources for people who are willing to access them. This may open up new science support opportunities. The field might also consider ways to support families without consistent Internet access to answer these "just-in-time"-curiosity questions that could lead to learning opportunities and spark additional curiosities and motivation to learn in science. Interventions might be developed to assist parents and teachers with anticipating and recognizing behaviors in very young children (e.g., prolonged attention, consistent book and toy selections) and motivating them to respond with opportunities for further engagement. One other question remains–Are parents as sensitive to the science-related content of some of their young daughters' questions as they are to the questions from their sons? The answer to this question will require a different level of analysis than we currently have available—a more conversational analysis—but one that is important to pursue.

APPENDIX ITEMS ASSESSING SLO: AGES 4, 5, AND 6

Item
Frequency of Activities
Has your child attended a concert or other musical event in the last year?
Has your child visited an art museum in the last year?
How often do you attend these events (greater than 8 times per year = 4 points; less than once a year = 1 point; never = 0 points)
Museum or art exhibit
Attend a concert
Go to the theatre
Go to the movies
At Age 6, the following items were added:
How frequent are visits to specific science-related community activities over last year?
Amusement Parks
Clubs such as Boy Scouts or Girl Scouts
Sport-related courses like swimming or martial arts

There were no significant differences between boys and girls on any of these items

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