EARLY CHILDHOOD SCIENCE INTEREST DEVELOPMENT: VARIATION IN INTEREST PATTERNS AND PARENT-CHILD INTERACTIONS AMONG LOW-INCOME FAMILIES

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Abstract

Fostering interest in science is critical for broadening engagement with science topics, careers, and hobbies. Research suggests that these interests begin to form as early as preschool and have long-term implications for participation and learning. However, scholars have only speculated on the processes that shape interest development at this age, when children's exposure to science primarily occurs during family-based learning experiences. Moving beyond speculation, we conducted a qualitative study with seven low-income mothers and their four-year-old daughters from Head Start to (a) develop a descriptive understanding of science-related interest development for preschool children from traditionally underserved communities and (b) identify differences across families that might explain variation in children's interests. The study was conducted over five months and included two in-depth interviews and four videotaped sessions in which families engaged in science-related activities. Interviews suggested that children's science-related interests sparked by the sessions fell along a continuum, from *focused* interests specific to the materials provided during the sessions to *broad* interests extending to more general topics and activity types. We also found important variation across families related to mothers' expression of affect, their involvement and leadership styles, and their approach to re-engaging children when they lost interest or changed focus.

Keywords: informal science education, interest development, early childhood, family learning, proximal processes

Early Childhood Science Interest Development: Variation in Interest Patterns and Parent-Child Interactions among Low-Income Families

A central goal of science education and policy efforts over the last several decades has been to ensure a robust and diverse science and engineering workforce (Langdon, McKittrick, Beede, Khan, & Doms, 2011; National Science Board [NSB], 2010, 2014). Increasing participation in science across communities of all cultural and socioeconomic backgrounds is an issue of both practical and ethical concern, since it is broadly recognized that in order to maintain an innovative scientific enterprise in the U.S., all communities must have opportunities to learn about and engage with science and, ultimately, be equitably represented in the science workforce (Hill et al., 2010; National Academy of Sciences [NAS] et al., 2011; NSB, 2010). In addition, addressing issues of declining interest and participation in science is necessary to ensure that adults are able to function successfully in an increasingly scientific and technological world (NAS et al., 2011; Osborne, Simon, & Collins, 2003).

Despite national consensus on the importance of these issues, major disparities persist between men and woman and across racial, ethnic, and socioeconomic groups in terms of science-related academic achievement, workforce participation, and access to science learning opportunities inside and outside of school. According to the NSB (2014), the substantial gaps across racial and ethnic communities in science and mathematics school achievement, the proportion of students earning advanced mathematics and science credits, and high school graduation rates remain persistent challenges in K-12 education. Similarly, women and minority racial and ethnic groups, in particular those from African Americans and Hispanic/Latino communities, continue to be underrepresented in the science and engineering workforce (Hill et al., 2010; NSB, 2014). Income level and socioeconomic status are strongly associated with access to learning resources and academic performance and often interact with gender, racial, and ethnic equality in STEM achievement and participation (Ainley & Ainley, 2011a; Corbett, Hill, & St. Rose, 2008; Gershenson, 2013; McGraw, Lubienski, & Strutchens, 2006). Families from low-income backgrounds face a variety of barriers to accessing and engaging with science learning resources and experiences, including financial and geographic accessibility, personal and cultural relevance, work schedules, transportation, and more (Lareau, 2003; National Research Council [NRC], 2009; NRC et al., 2003)

In addition to addressing issues of preparation, access, affordability, and academic and social support, researchers and policymakers have identified interest and motivation as key leverage points for addressing these disparities (NAS et al., 2011; NRC, 2005, 2009). *Interest*, often defined as a heightened emotional state of engagement, as well as a predisposition to reengage with a particular object, event, or topic (Hidi & Renninger, 2006), is a critical factor driving long-term engagement with science (F. S. Azevedo, 2013; Falk, Osborne, & Dorph, 2013; Falk et al., 2016; Maltese & Tai, 2010; National Research Council, 2009; Tai, Liu, Maltese, & Fan, 2006) and a central component to successful learning (See reviews by Hidi & Renninger, 2006; Renninger & Hidi, 2011; Renninger & Su, 2012). Interest triggered in a particular moment can set the stage for the development of more enduring individual interests (Hidi & Renninger, 2006), which extend beyond a specific context. These individual interests can, in turn, lead to identity development (Alexander, Johnson, & Kelley, 2012; Renninger, 2007) and career and hobby pathways (Archer et al., 2010; McCreedy & Dierking, 2013; Packard & Nguyen, 2003; Watt & Eccles, 2008). Scholars have argued that interest is critical for science learning and achievement in particular, motivating individuals to focus attention on science topics and activities, identify and seek answers to meaningful science questions, engage and persevere in science learning experiences, and develop positive attitudes toward science (Renninger, 2007; Renninger & Su, 2012).

Although the focus of interest and interest development research is often on school-age children (e.g., Ainley & Ainley, 2011b; F. S. Azevedo, 2011; Barron, 2006; Falk et al., 2016; Frenzel, Goetz, Pekrun, & Watt, 2010), there is growing evidence that children develop enduring interests, including those related to science, before they enter school and that these interests persist over time and have implications for long-term learning trajectories (e.g., Alexander et al., 2012; Fisher, Dobbs-Oates, Doctoroff, & Arnold, 2012; Patrick, Mantzicopoulos, Samarapungavan, & French, 2008). As these findings emerge, researchers are just beginning to investigate how science-related interests develop for preschoolers and the factors that influence these processes. Investigators have *described and documented* the many ways that preschool children and their families engage in scientific activities and learning practices in a variety of settings (NRC, 2009). However, there has been almost no research to *explain* the processes and mechanisms through which these experiences influence children's developing science-

related interests or identify the salient characteristics of parent-child interactions (proximal processes), especially among families living in low-income, under-resourced communities. Such information is critical for staff and organizations that support families living in these communities, as well as for policymakers focused on equitable STEM and early childhood education.

Recognizing the current state of the field, the purpose of this study was to develop a rich, descriptive understanding of the nature of science-related interest development among preschool children from low socioeconomic backgrounds and explore differences and similarities across the families in parent-child interactions that might explain variation in children's science interest development patterns. The qualitative study reported in this article was part of a larger, mixed-method investigation conducted in collaboration with the Mt. Hood Committee College (MHCC) Head Start program and the Oregon Museum of Science and Industry (OMSI). The initial phase of the study was a quantitative, cross-sectional survey with 138 Head Start parents and caregivers[1] to explore relationships between parent characteristics, child-rearing beliefs, science interests, and science learning practices (Pattison, 2014). Using findings from this phase, we recruited a group of seven mother-daughter dyads for a more in-depth, qualitative investigation.

Early Childhood Interest Development

Although historically many scholars have argued that preschool children are not capable of exhibiting enduring, stable interests, research over the two decades has found that many young children do indeed develop domain-specific interests that persist for months and even years (Alexander, Johnson, & Leibham, 2015; Leibham, Alexander, & Johnson, 2013; Neitzel, Alexander, & Johnson, 2008; Renninger & Su, 2012), including interests in science-related topics and activities, such as birds, dinosaurs, mathematics, and more (Alexander et al., 2012; DeLoache, Simcock, & Macari, 2007; Fisher et al., 2012; Pattison et al., 2018). There is also growing evidence that these interests persist and have implications for children's behavior and learning before and after they enter school. Researchers studying early childhood interest in general have found that (a) children as young as three have strong and individualized interests focused around activities, objects, themes, or topic domains; (b) gender differences in these interests are already apparent at this early age; and (c) these interests are associated

with attention, recall, play behaviors, and temperament and persistence (Fink, 1994; Renninger, 1989; Renninger & Leckrone, 1991; Renninger & Wozniak, 1985; Rowe & Neitzel, 2010). Early childhood interests have also been associated with how children later participate in classroom activities during kindergarten (Neitzel et al., 2008). Specific to science, several studies have found meaningful differences in children's science interests as they enter school (Mantzicopoulos, Patrick, & Samarapungavan, 2008; Patrick et al., 2008). Recent longitudinal studies (Alexander et al., 2015; Leibham et al., 2013) suggest that, controlling for other factors, the intense science-related interests of four-year-old children predict science self-concept and knowledge four years later, especially for girls. For the children in these studies, early science interest was a stronger predictor of self-concept and knowledge than current science interest (Leibham et al., 2013).

Building on this work, researchers are just beginning to explore the factors influencing science interest development among preschool children. There is substantial evidence that parents and children of this age frequently engage in scientific activities and learning practices that may offer an important context for science-related interest development (e.g., Callanan & Jipson, 2001; Crowley et al., 2001; Fender & Crowley, 2007; Mehus, Stevens, & Grigholm, 2013; Palmquist & Crowley, 2007; Rigney & Callanan, 2011; Valle & Callanan, 2006). Scholars have speculated on a number of ways that caregivers might influence children's developing interests during these experiences, such as communicating important beliefs and values or answering curiosity questions (Alexander et al., 2015; Barron, Martin, Takeuchi, & Fithian, 2009; Frenzel et al., 2010; Leibham, Alexander, Johnson, Neitzel, & Reis-Henrie, 2005; Tenenbaum & Leaper, 2003). Researchers have also identified several distal factors that appear to be associated with children's sustained interest in science, including parental beliefs about academic stimulation, satisfying their children's curiosity, providing interest-related materials and learning opportunities, consistency and structure, and the value of communication (Johnson, Alexander, Spencer, Leibham, & Neitzel, 2004; Leibham et al., 2005). However, beyond this handful of studies, how these experiences influence science interest development, and the characteristics of parent-child interactions that are particular salient, are not well understood. This is especially true for families from low-income

communities, since the majority of early childhood science interest development research to date has been conducted with white, middle-class families.

Theoretical Framework

In order to develop a deeper understanding of the processes influencing early childhood science interests, we drew from two theoretical frameworks: (a) the four-phase model of interest development (Hidi & Renninger, 2006; Renninger & Hidi, 2011) and (b) the bioecological model of human development (Bronfenbrenner, 1979; Bronfenbrenner & Morris, 2007). Within the field of science education and learning, Renninger and Hidi have developed one of the most extensively used and empirically supported theories of interest development (NRC, 2009). Their model defines interest broadly as "the psychological state of engaging or the predisposition to reengage with particular classes of objects, events, or ideas over time" (Hidi & Renninger, 2006, p. 112) and individual interest, specifically, as a “a person's relatively enduring predisposition to reengage particular content over time as well as the immediate psychological state when this predisposition has been activated" (p. 113).

This theoretical perspective places individual interest at one end of a continuum of four phases of interest development (Hidi & Renninger, 2006), including two phases of situational interest (triggered and maintained) and two phases of individual interest (emerging and well-developed). The phases are characterized by varying amounts of affect, knowledge, and perceived value related to a specific topic or activity, with earlier phases of interest primarily consisting of focused attention and positive affect, while later phases incorporate knowledge and value constructed over time. Recently, Renninger and colleagues have further refined the model to highlight how different configurations of the phase of interest development, the achievement demands of the learning environment, and metacognitive awareness require different supports for interest development (Renninger & Su, 2012).

The bioecological model, defined as a “theoretical system for the scientific study of human development over time" (Bronfenbrenner & Morris, 2007, p. 753), makes two central claims: (a) proximal processes, or the ongoing, direct experiences of an individual with his or her environment, including other individuals, are the primary engines of development; and (b) the impact of these proximal processes are indirectly influenced by personal, environmental, and temporal factors that are more or less distal to the

direct experiences of the individual. From an analytic perspective, these claims assert that proximal processes, such as caregiver-child interactions, should have a direct association with developmental outcomes, while other contextual factors, such as the availability of learning resources or child-rearing beliefs, should be indirectly associated with those outcomes, either mediated through proximal processes or moderating the relationship between those processes and children's learning and development. Bronfenbrenner and Morris also posited that in order to have a significant influence on an individual's development, proximal processes must be fairly consistent and ongoing.

Together, these perspectives shaped the design of the study, guided data collection and analysis, and heightened our attention to particular aspects of the data and research contexts. We conceptualized interest as a developmental, phased process, beginning with triggered situational interest in a particular moment and context and, in some circumstances, developing into more enduring individual interest. We also assumed that proximal processes, and especially ongoing interactions with parents and caregivers (Bronfenbrenner & Morris, 2007; NRC, 2000a; Vygotsky, 1978), are the primary influence on children's developing interests, especially before children enter kindergarten.

Research Questions

Guided by this theoretical framework and the interest development literature, our study was designed to address two broad research questions:

a) What does science-related interest development look like for four-year-old children from low socioeconomic backgrounds?

b) What are differences and similarities in patterns of parent-child interactions among these families that potentially influence the development of preschool children's early science-related interests?

The study was intended to contribute to theory and practice in several ways. First, building on research indicating that young children do show evidence of persistent science-related interests, we intended to document *how these interests develop* over the course of several months through multiple science-related experiences and ongoing interactions with parents from low-income communities. Because most discussions of the associations between parenting strategies and early childhood interest development have been speculative, we also hoped to identify distinct areas of *variation in the proximal*

processes of parent-child interactions among families that might provide a more evidence-based focus for future research. Aligned with asset-based perspectives (e.g., Gutiérrez & Calabrese Barton, 2015; Gutierrez & Rogoff, 2003; Lareau, 2003), our goal was also to avoid normative assumptions about parenting from our own experiences or research with middle- and upper-income families. Instead, we attempted to shed light on the patterns and processes of early childhood science-related interest within low-income communities and ways that researchers and educators might support these families in fostering long-term interest development.

Methods

To investigate the research questions described above, seven mothers with four-year-old daughters and varying levels of science interest were recruited for an in-depth, qualitative study involving interviews and videotaped observations of the families interacting in a variety of science-related contexts. Qualitative research is a broad approach to scientific inquiry that, in contrast to quantitative methods, emphasizes discovery and emergent findings, the subjective experiences of participants and researchers, and the exploration of the complexities of specific contexts and settings (Morgan, 1998, 2014). The approach is particularly appropriate when existing theories and empirical findings are lacking and there is a need to capture the complexities of social systems and identify patterns that can be further explored in subsequent studies (Creswell, 2013; Marshall & Rossman, 2011).

In this study, only mothers were selected in order to eliminate parent gender as a source of variation and because the vast majority of participants in the larger mixed-method study were female. Similarly, we focused on families with four-year-old children in order to eliminate differences due to child age. Research highlights four years as a critical time period in which children are beginning to develop understandings of themselves relative to social and cultural norms (e.g., Goodvin, Meyer, Thompson, & Hayes, 2008; Ontai & Thompson, 2008; Thompson, 2006) and exhibit signs of emerging interests in science-related topics and activities that have been associated with behaviors and attitudes later in elementary school (e.g., Alexander et al., 2012, 2015). Girls were specifically chosen because gender has been identified as an important factor influencing early science interest development (Alexander et al., 2012; DeLoache et al., 2007; Leibham et al., 2013; Neitzel et al., 2008) and because

connections between children's indications of early science interest, opportunities afforded by parents to caregivers to engage with science, and later enduring science-related interests may be stronger for girls (Alexander et al., 2012). More broadly, researchers have documented persistent gender disparities in extracurricular opportunities to engage with science (Brotman & Moore, 2008), suggesting a need to focus particularly on science engagement and interest development for girls from an early age.

Participant Recruitment

Participant selection and recruitment were conducted through the initial survey and in close collaboration with MHCC Head Start program staff. Given the persistent disparities in lifelong science engagement across socioeconomic groups, we chose to work with families in poverty from diverse racial and ethnic backgrounds in the hopes of identifying interest support strategies and factors of particular relevance to these communities. With the paucity of research focused on families living in low-income, under-resourced communities, it was critical to identify a community-based research partner with strong relationships with such families. Thus, we partnered with the MHCC Head Start program. Head Start, administered within the Administration for Children and Families in the U.S. Department of Health and Human Services, promotes school readiness among children under five living in poverty. MHCC Head Start staff members were close collaborators throughout the research, informing study design, supporting participant recruitment and data collection, and partnering on subsequent projects (e.g., Pattison et al., 2017). As noted, we did not attempt to compare low-income families with those from wealthier backgrounds in order to avoid normative assumptions about "correct" parenting approaches (Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003). Instead, our goal was to identify existing strengths and promising strategies within low-income communities that could be further supported to promote early childhood science interest development.

In total, eight mother-daughter dyads were recruited. One family, originally contacted by Head Start program staff, dropped out after the first session without completing the survey and therefore was only included in initial coding and analysis. As incentives for participating, each family was offered a one-year membership to OMSI and the variety of science activities and learning resources used during the study. To minimize the influence on parent and child behaviors, families were told that the broad goal of

the study was to understand child-rearing and early childhood development but were not informed of the specific focus on science-related interests until the end of the second interview.

Activity Sessions

Four different data collection sessions were designed to represent social contexts in which child-rearing practices are salient and science-related discourse was likely to be elicited: (a) reading a science-related book together at home; (b) visiting Science Playground, the early childhood space for six-year-olds and younger at OMSI; (c) using science-related activity boxes at home; and (d) engaging in a science-related activity of their own choice. Each session balanced the need to maintain naturalistic parent-child interactions, provide a degree of contextual consistency across families, and capture discourse and interactions potentially related to science interests (Snow et al., 2008). These four contexts have also been the frequent focus of science learning research and collectively represent common ways that preschool children and their families engage with and learn about science (e.g., Barnyak, 2011; Leung, 2008; NRC, 2009; Siegel, Esterly, Callanan, Wright, & Navarro, 2007; Tenenbaum & Callanan, 2008; Wertsch, Minick, & Arns, 1999). Although previous studies have focused on each of these contexts, no research to date has looked at the proximal processes and patterns of science interest development that occur across contexts within the same family. All activities and materials used during the sessions were previously prototyped with two mother-child dyads not involved in the study.

In the first session, we brought three science-related books (Fredericks, 2011; McDonnell, 2011; Yaccarino, 2012), chosen in consultation with early childhood science education experts at OMSI, to the families' homes and asked them to read together as they typically would. In the second session, we invited mother-child dyads to visit Science Playground at OMSI. In the third session, similar to the joint book reading, we brought two open-ended science activity boxes, "exploring natural materials" and "exploring bubbles," both based on NSF-funded projects at the Boston Children's Museum (Boston Children's Museum, 2012, n.d.), to the families' homes and asked them to explore the activities in any way they chose for as long as they wanted. For the final session, mothers were asked to pick an activity to do with their daughters that they felt was related to science. This session was deliberately designed to help capture family engagement with not only science-related activities provided to families but also activities

and science practices already embedded within family routines. Without prompting, all six of the families that participated in the family choice session chose an outdoor nature walk experience. Five of the families chose walks in a park or natural area and one chose a walk in the neighborhood to collect leaves followed by a leaf rubbing activity.

Observations

Between January and August 2014, the first author observed and videotaped each family in the four different contexts, following best practices in video-based research (Barron, 2007; Derry et al., 2010). Field notes collected during these initial observations were also included as part of data analysis.

The protocol for observations varied depending upon the session. For the reading and activity box sessions, the first author brought the materials to the families' homes at a prearranged time, set up the video camera in a location chosen by the families, briefly introduced the materials, and left the mothers and children to interact on their own, asking families to text when they were finished. During the OMSI visit, the first author met families at the front entrance to the science center and escorted them to Science Playground. At this point, families were invited to explore the exhibits for as much or as little time as they wanted while the researcher followed at a respectful distance with the video camera. Videotaping ended when either the digital camera was full (approximately one and a half hours) or families decided to leave the early childhood space.

The protocol for the family choice session was similar. The first author met the families in a predetermined location, usually their homes, and then videotaped the mothers and children engaging in the chosen activity or visiting the chosen location, following at a respectful distance with the video camera. Again, videotaping ended when either the digital camera was full or the families decided they were finished.

Interviews

Qualitative, semi-structured interviews (Patton, 2015) were conducted with each of the mothers after the OMSI visit (session 2) and after the family choice session (session 4) in order to gather evidence of children's developing interests, explore parent perspectives on the interactions, and check our interpretations of the video data. During the interviews, we used pre-prepared segments from previously

videotaped parent-child interactions to explore situation-specific beliefs and perspectives and prompt reflection, similar to stimulated recall approaches used by other researchers (e.g., Ash, 2004; Derry et al., 2010). All interviews were videotaped and analyzed with the interaction data, as described below. All seven of the families included in the full data analysis were able to complete both rounds of interviews.

Data Analysis

For this study, we adopted a constructivist grounded theory approach, particularly informed by the recommendations of Charmaz (2006). Although the qualitative research process is not linear, in general we followed three phases of analysis: (a) initial coding, (b) focused coding, and (c) interpretation. Using NVivo analysis software, video data from the sessions and interviews were coded directly. Throughout the data analysis, we wrote descriptive and interpretive memos to document the analytic process and ensure that our interpretations remained grounded in the data and participants' perspectives. We also used the constant comparative method (Charmaz, 2006; Glaser & Strauss, 1967), including comparing data within and across participants and settings, during each phase to guide and motivate the analysis.

During initial coding, the first author reviewed all of the videotaped sessions and interviews incident by incident and utterance by utterance, assigning short, low-inference codes that captured the essence of the participants' actions and talk. This process resulted in numerous tags and annotations that were then carefully reviewed in order to draft a focused-coding framework for the next stage of analysis. To guide the selection of these focused codes, the researcher used concepts from prior literature and theory, the salience of codes to the study's research questions, the frequency of common actions and comments in initial coding, evidence of the importance of a situation for shaping interest and interest development, and ideas that emerged in field notes and early analytic memos. During this stage, the second author also reviewed a subset of the sessions and interviews and both authors met to discuss critical interactions and emergent themes and patterns. These discussions informed the draft focused-coding framework and provided a check on the first author's interpretations and assumptions.

In the next stage, the focused-coding framework was revised and applied systematically to all of the videotaped sessions and interviews from the seven families that completed the study. Initially, the first

author applied the framework to a subset of codes and used this process to clarify and refine code definitions. This revised framework was then sent to the second author and one other researcher with extensive video coding experience who had not been involved in the study previously. These two individuals used the updated coding framework to analyze a subset of the interview and session videos. The three researchers then met to discuss and revise the coding framework, including clarifying and refining code definitions, removing and revising codes that made unjustified assumptions or value statements about family actions and comments, adding codes to capture critical aspects of the interactions and interviews that had been missed previously, and reorganizing the framework to reflect emerging ideas about the nature of the interactions and the factors and processes influencing interest development. Finally, the first author applied this revised coding framework to all of the video data, continuing to clarify code definitions as needed. This process resulted in approximately 5000 coding references for the 14 interviews and 26 family sessions.[2]

Relevant to this study, three distinct sets of codes emerged during this analysis process: (a) indicators of interest and interest development, (b) holistic parent-child interaction characteristics, (c) and micro-level parent and child behavior. In the first category, we developed a set of codes to capture child situational interest and interest loss during the sessions, including indicators of interest loss, factors that appeared to precipitate interest loss, strategies mothers used to respond, and short-term outcomes of the interactions. Similarly, we developed a set of codes to capture evidence from the interviews about child interests sparked during the sessions that were sustained beyond the particular experiences, as well as the types of interests that were sustained.

The second category of codes included holistic characteristics of the sessions and interviews. These were intended to capture general patterns of parenting, parent-child interactions, and parenting beliefs, such as parent leadership style, and were applied to each video as a whole. At the same time, we also developed “micro” codes that were applied to specific actions, comments, and instances within the videotaped sessions, such as parent- or child-initiated changes in session focus. These codes were intended to both identify more nuanced patterns of interaction potentially related to children’s interests and interest development and to provide a check for the holistic codes.

The final stage of the analysis process was interpretation, or moving from coded data segments to broader, more theoretical statements about patterns and processes highlighted by the codes. This stage included extensive memo writing to explicate codes and code categories and begin to describe and organize patterns within the data, strategic comparisons within the dataset, and ongoing discussions between the first and second author. Potential themes were identified, along with supporting evidence, leading to further analysis and comparisons. During this process, we also used a negative case analysis approach, involving the search for data that disconfirms or contradicts the researcher's hypotheses and leads to subsequent revisions (Creswell, 2013).

Findings

The analysis process resulted in a rich description and understanding of children's emerging science-related interests and the ways that mothers and children interacted around the science-related activities. We begin by describing the characteristics of study participants and their experiences with the sessions in general. We then focus the remainder of the findings section on evidence of interest development sparked by the study and variation in patterns of parenting among families potentially related to these interests.

Study Participants

Table 1 provides a summary of mother characteristics for the seven families that completed the study.[3] Overall, the participants represented a range of backgrounds, family structures, education levels, and beliefs and interests related to science. Three of the families were involved in full-day Head Start, specifically designed for working parents and caregivers, while the remainder had children in part-day programs. The age of the mothers ranged from 22 to 37. Most of the families had two adults in the household, although two parents were single mothers, and the number of children in the house ranged from 1 to 3. Several of the parents with older children reported having had families with a previous partner. Two mothers identified as Black, one as Black and American Indian/Native Alaskan, one as Mexican, and three as White, not Hispanic/Latino. Most parents had none or only some college experience, although one reported completing a bachelor's degree. Based on their responses to the initial survey, most parents expressed neutral to positive values towards and interest in science and most

reported hardly ever engaging in science-related learning activities, such as watching a science TV program or reading a science book. Although socioeconomic data were not collected, all families were low income based on their eligibility for the Head Start program.[4]

Table 1. *Participant characteristics*

Name	HS program	Age	No. adults in house	No. children in house	Work	Ethnicity	Race	Highest degree
Raymona	Part-day HS, EHS	30	1	3 (0–3, 4, 6–9)	Caring for children, house keeper.	Not Hispanic/Latino	Black	Some college credit (no degree)
Tanisha	Full-day HS	22	1	1 (4)	Drive thru cashier, cleaning.	Not Hispanic/Latino	Black	Some college credit (no degree)
Darlene	Part-day, EHS, PAT	26	2	2 (0–3, 4)	Teaching my children life skills.	Not Hispanic/Latino	White	Grade 1 through 11
Emily	Part-day HS	36	2	2 (4, 13–15)	Cleaning and caring for my kids.	Not Hispanic/Latino	White	Regular high school diploma
Sabrina	Full-day HS	23	2	2 (0–3, 4)	Caring for disabled adults	Not Hispanic/Latino	Black, AI/NA	Some college (no degree)
Michelle	Full-day HS	35	2	3 (4, 5, 13–15)	Customer service	Mexican	White	Some college (no degree)
Maddy	Part-day HS	37	2	3 (4, 6–9, 13–15)	Volunteer work with daughter's school	Not Hispanic/Latino	White	Bachelor's degree

Note. Adults in household includes participant. EHS = Early Head Start. PAT = Parents as Teachers. For number of children in house, ages of children are shown in parentheses, as reported in the phase 1 questionnaire.

Across the families, the data set included 26 sessions and 14 videotaped interviews, representing approximately 27 hours of video, in addition to field notes and analytic memos. The length of time between the first consent meeting, which preceded the reading session, and the final interview ranged between 40 and 79 days, with an average of 64 days. The length of time between the reading session and the final interview was similar, ranging between 32 and 67 days, with an average of 51 days. Families' schedules were often complicated and parents frequently had to reschedule appointments during the study. Two of the families were not able to participate in the OMSI visit because of reoccurring scheduling and transportation challenges and one family was not able to participate in the family choice session for similar reasons.

The length of the observations varied by session type. Time spent during the reading sessions ranged from 24 to 52 minutes, with an average of 36 minutes. All the families spent at least a small amount of time on each of the three books. For the OMSI visit, videotaping time ranged from 35 minutes to 90 minutes, with an average of 54 minutes, and many of the families indicated that they had spent additional time in other areas of the science center after the videotaping was complete. All but one of the families tried both of the activities for the activity box session, spending from 28 to 63 minutes during the session, with an average of 44 minutes. The length of the outdoor family choice experiences ranged from 11 to 63 minutes, with an average of 33 minutes.

Early Childhood Interest Development

During interviews with parents, it became clear that the sessions had sparked interests that, in many cases, extended beyond the specific experiences. Both prompted and unprompted, parents described how, through participation in the study, their children had become interested in a variety of objects and activities, including rotting logs and bugs, chipmunks and squirrels, Jane Goodall, rocks and gems, using magnifying glasses, collecting natural objects, and more. For some of these families, the period between when the initial interest was sparked and when the parents reported the sustained interest was quite long. As noted above, the time from the first reading session to the final interview ranged between 32 and 67 days. Therefore, some of the interests sparked during the first reading session were still evident to parents two months later.

Although all of the parents reported sustained interests beyond specific sessions at some point during the study, the breadth of these interests and the degree to which they transferred to other contexts fell along a continuum. For some families, children's new interests primarily focused on the specific books, materials, or activities from the sessions (e.g., bubbles, polished rocks, chipmunk costume) or memorable experiences from the study (e.g., visiting OMSI, getting a special book). For example, when asked if anything had stuck with her child after the sessions, Emily mentioned that her daughter continued to be fascinated by the polished rocks that were part of the activity boxes: "She kind of liked the rocks. Well, she loved the rocks… She likes carrying the rocks everywhere."

At the other end of the spectrum, some parents discussed ways that their children's sustained interests had extended to broader topics and skills or had transferred to new situations. Comments during the interviews provided evidence that, in addition to re-engaging with particular materials or activities presented during the sessions, children were becoming fascinated with general topics (e.g., the ocean, chipmunks, plants and trees, monkeys) or were showing a preference for a behavior or skill (e.g., collecting leaves, comparing and measuring). In describing these broad, sustained interests, parents often constructed narratives about connections with prior experiences and future opportunities for supporting and developing their children's interests.

Michelle's family

Michelle and her daughter represented a typical example of a family in which the child's interests sparked by the sessions focused specifically around the materials and topics from the study. When asked if anything had stuck with her daughter after the activity box session, Michelle described how her daughter had continued to play with the polished rocks:

> *She played with them more, not that same day, but she's been playing with them throughout. And she'll be like, look at my pretty gems. I mean that was cute too… You know, she would separate them. She gave me one. She said, 'this is for you to keep.' And I was like, 'oh, thank you. (Michelle, interview #2)*

According to Michelle, she wasn't surprised that her daughter had liked the rocks and imagined it was the type of thing she would have wanted to buy at the OMSI science store. Similar to other parents, Michelle also talked about how her daughter had played with the bubble activity several times since the videotaping session, constructing bubble wands and other creations from the pipe cleaners. When asked if anything had stuck with her daughter after the reading session and OMSI visit, Michelle indicated that nothing had come up so far.

Sabrina's Family

At the other end of the spectrum, Sabrina described a variety of ways her daughter expanded her interests beyond the specific materials and topics presented during the sessions. In the first interview,

without prompting Sabrina mentioned how reading the *Me… Jane* book (McDonnell, 2011) had initiated a cascade of related interests with her daughter:

> *Yeah, [she's become interested in] the monkey. That's all she wanted to see at the zoo, too… She usually likes the giraffes but it's all about monkeys lately… She always just talks about the monkey and Jane. She's like, "I like monkeys; I could be like Jane." (Sabrina, interview #1)*

Even as her daughter's interests expanded to the more general topics of monkeys and Jane Goodall, the book itself continued to have special meaning. According to Sabrina, her daughter cherished the book as a special gift ("These are the books that Scott got me, Scott bought me these books"), asked to read the book regularly, took it with her to other houses, and enjoyed telling family members about her book and how she had received it. Sabrina's daughter also had a special affinity for the bubble activity box, regularly initiating the activity yourself: "Yeah, they do it themselves. She pours the Dawn herself, she pours the cornstarch, she adds the water. She can go grab the container and set herself up, from blowing the bubbles, to popping the bubbles, to cleaning it up and putting it away."

Maddy's Family

Maddy provided a different example of children's interests broadening beyond specific materials. She and her daughter had both appeared to enjoy the natural materials box and had spent much of the videotaped activity session exploring and sorting the leaves and rocks. Rather than limiting herself to re-engaging with this activity box, however, Maddy's daughter began to show an affinity for sorting and categorizing natural materials in other contexts:

> *Yeah, actually I think [she is more interested in] looking at the different leaves and stuff. We do a gardening thing on Wednesday nights and she was, and it was actually her that did it, she was looking at the different types of leaves and which ones look the same and which ones didn't. Because the teacher or educator was telling us what the different plants were and which were ready to be harvested and so I think she took more of an interest than she would have done before. (Maddy, interview #2)*

Other Families

Of the families that participated in the study, four reported evidence of *broad* sustained interests (Maddy, Raymona, Darlene, Sabrina) on the part of their children, as defined above, while the three remaining parents (Michelle, Tanisha, Emily) primarily described *focused* sustained interests directly connected to the activities and materials presented during the sessions, without indicating that these interests had generalized to broader topics or had transferred to new contexts. Although the differences were subtle, the two distinct interest development patterns share similarities with Hidi and Renninger's (2006) differentiation between maintained situational interest and emerging individual interest, potentially indicating a key transition in young children's exploration of science-related topics and activities. The findings also suggest ways that early childhood science-related interests might be malleable, shaped by support from and interactions with their parents and caregivers.

Parent Engagement

Given the different science-related interest patters observed in this study and past research, we also focused the analysis on factors that were potentially associated with these differences. Understanding the proximal processes through which parents and caregivers influence their young children's science-related interest development begins by documenting variation in parents' approach to engaging with their children around science-related topics and activities. Through our inductive coding and analysis of the video data across three different contexts, a variety of apparent differences emerged in terms of how actively the mothers were involved with their children during the interactions, the roles they assumed, and how they expressed their own emotional engagement to their children. These included expressions of affect, level of attention and distraction during the activities, leadership style, extended parent and child question and answer exchanges, scaffolding to diminish and support children's choice and control, and strategies for re-engaging children during moments of situational interest loss. Here we highlight three of these aspects of parent involvement during the interactions that appeared to be particularly distinct across families and, based on prior theory and speculation, are likely to relate to children's interest development: (1) expressions of positive affect, (2) leadership style during the activities, and (3) approaches to responding to children's situational interest loss. As above, in describing these three themes, we highlight

examples of families representing each end of the variation spectrum and then compare these examples to what we observed across all participants.

Parent Affect

Enjoyment has consistently been found to be a central component of interest and interest development (Ainley & Ainley, 2011b; Hidi & Renninger, 2006) We were, therefore, not surprised to find apparent differences across the families in the degree to which parents were explicit in their expressions of positive affect and enjoyment during the sessions. Our general impression of these differences that emerged from the qualitative analysis was supported by the video coding. As part of the micro-interaction coding framework, we identified instances during the sessions in which parents made a verbal sign of positive affect or interest, including statements of "like" or "love" related to the activity, exclamations of interest or enjoyment, and praise for children. We also coded verbalized instances of parent negative affect or emotions, such as statements indicating frustration, disinterest, impatience, or anger.[5] In general, parents expressed far more instances of positive affect than negative, with an average of just under 10 instances of positive affect per session, compared to approximately one instance of negative affect on average per session. For some parents, however, the balance between these two was more extreme.

Maddy's Family

Maddy was an example of a parent that was particularly expressive and communicated more explicit positive emotions during the sessions compared to other parents. Maddy was coded for a total of 55 instances of positive affect (just under 14 per session on average) and zero instances of negative affect across the entire study. She frequently praised her daughter, expressed her enjoyment of the experiences, and indicated interest in the topics or materials. A typical example of this can be seen from the reading session, when Maddy and her daughter were sitting together on a chair at home reading the *Me… Jane* book:

> *Daughter: A chicken! (Pointing to a picture of a chicken in the book as Maddy turns the page)*
>
> *Maddy: There comes one!*
>
> *Maddy: "They hid behind some straw and stood very still…" (Reading from the book)*

Maddy: Here comes the chicken. (Turning the page)

Daughter: Bock, bock, bok, bok. (Making a chicken sound)

Maddy: "And observed the miracle…" What happened?

Daughter: An egg!

Maddy: Where did the egg come from?

Daughter: From the chicken. (After pausing for a minute)

Maddy: You're right. (Smiling and turning the page)

Daughter: Oh, look at those chickees, they're all over the place!

Maddy: Oh, that's so cute!

In this example, Maddy reinforced her daughter's excitement about the book (e.g., "Oh, that's so cute!") and modeled her own interest through exclamations (e.g. "There comes one!"), asking questions about the story ("Where did the egg come from?"), and affirming her daughter's answers. Across all the sessions, Maddy took a similar approach, showing her own interest in the experience or activity and reinforcing her daughter's positive emotions.

Michelle's Family

As with all the parents, Michelle primarily showed signs of positive affect during the sessions (38 total, or just under 13 on average per session). Compared to Maddy, however, Michelle had a higher number of instances of negative affect (6 total, or 2 on average per session). For Michelle, many of these instances of communicating negative affect arose during the reading session, when she made several comments that suggested the books were too long or not age appropriate (e.g., "those are long books!"). After going through the first two books, her daughter asked her to read the third one about rotting logs. At this point, Michelle began to express some frustration:

Daughter: Mom! (Handing her the third book)

Michelle: Oh, geez. (Opening the book to the first page of text and looking tired)

Michelle: "Dear visitors, I live in a great place, a rotting log…" (Beginning to read)

Michelle continued reading each page, with her daughter sometimes playing separately and sometimes sitting on the couch with her. The third book they read is designed with a repeating series of

phrases about animal life in a rotting log. At one point, Michelle commented that "It's the same words" as she turned the page. Several minutes later, Michelle communicated a negative emotional response that was quickly taken up by her daughter:

Michelle: Eww, I don't like this one! (Commenting on the picture of a snake as she turns the page)

Daughter: What happened? (Returning to the couch to look at the picture)

Michelle: This one's scary.

Daughter: Let me see!

Michelle: Eww! "A gray snake in search of some prey…" (Beginning to read)

Daughter: Eww, I don't like it! (Running away from couch as mom continues to read)

Other Families

These two examples highlight the range in explicit affect communicated by parents during the sessions. Importantly, we do not suggest that this variation reflects the actual emotions that parents felt during the sessions, but rather the emotional signals they communicated to their children. Across the families, some parents were more similar to Maddy in the ways they showed positive affect. For example, Raymona was coded for a total of 64 instances of positive affect (16 on average per session) and only one instance of negative affect. In contrast, Tanisha was more similar to Michelle, with only 15 coded instances of positive affect across all the sessions (5 on average per session) and just about half as many instances of negative affect (8 in total, just over 2.5 on average per session). Other families fell in between these extremes, with 21 to 32 total instances of positive affect (8 to 13 per session on average) and 1 to 4 instances of negative affect (less than one on average per session). Even though some of these differences among families were likely due to variation in the length of the sessions, there were still fundamental distinctions in the emotional signals communicated by parents and the relative balance between number of expressions of positive and negative affect. Some children experienced ongoing, consistent positive feedback from their parents and saw the adult modeling interest in the science topics and activities. Other children experienced more reserved affect and more frequent expressions of frustration or disinterest.

Parent Leadership

There was also notable variation among families in the roles that mothers adopted during the sessions, either as active leaders or more passive followers or co-learners. As part of the holistic session coding framework, we classified session leadership dynamics in terms of whether the session overall was child led, parent led, or a mixed leadership style. Sessions coded as child led were characterized by children primarily choosing and directing the focus of the activities and sessions and setting the pacing and direction for shifts in focus. Parent-led sessions were characterized by the adults directing the activities and setting the pacing. Finally, some sessions were characterized as mixed leadership style and included both extended parent-led and child-led sections.

These differences in overall parent leadership and involvement styles during the sessions were aligned with results from the micro-interaction coding. For example, we found that mothers adopted qualitatively different approaches to guiding and directing their children during the sessions, as indicated by large differences in the number of times per session that parents supported children's choice and control (e.g., asking the child to make a choice, making a comment that implied the child had a choice or was in control, or actively following a choice that the child had made), as well as diminished choice and control (e.g., setting guidelines, insisting on finishing one portion of an experience or activity, or redirecting a child towards a different choice). Some mothers took a very active role, frequently making choices for their children, setting boundaries and guidelines, and offering new choices and opportunities. Other mothers were more passive, allowing their children to make their own choices and explore the activities and experiences independently.

Darlene's Family

Darlene represented one extreme of this leadership continuum, with all of her sessions coded as parent led. She primarily took an active and involved approach to facilitating the sessions, introducing activities and tasks; laying out instructions and guidelines; determining when to change focus or move on to a new portion of the session, such as a new book, activity box, or OMSI exhibit; and deciding the topic and direction of conversation. For example, during her visit to Science Playground, Darlene spent much

of the time physically leading her daughter from one exhibit to the next, often providing an introduction before prompting her child to try the activity.

Darlene took a similar approach during the family choice portion of the study. For this session, she decided to collect leaves with her daughter from around the neighborhood and then show her how to make leaf rubbings with paper and crayons. After the walk through the neighborhood, Darlene led her daughter methodically through the process of setting up the materials, selecting colors of crayons for the rubbings, and choosing which leaves to try first. Once the daughter had selected the first leaf, Darlene demonstrated how to make a rubbing:

Darlene: Put the leaf on there, okay. (Laying a piece of paper flat and gesturing for the girl to lay the leaf on top)

Darlene: No here… okay, maybe we can keep that (repositioning the leaf on the paper after the daughter lays it down)

Dalene: No, stop. (Stopping her daughter from touching the leaf or using the crayon)

Darlene: Okay, so we're gonna… I'm gonna show you how to do it first and then you can do it. (Demonstrating how to fold the paper over the leaf as the daughter watches)

Darlene: You kinda have to hold the paper down a little bit, and mommy can help you. You take the crayon on its side… (Taking the crayon from the girl and demonstrating)

Darlene: Just wait. (Moving the girl's arm out of the way as she tries to use the crayon)

Darlene: We just color it… and see, it comes out showing all the lines and everything. (Demonstrating the rubbing for her daughter)

Darlene: Do you see that, isn't that cool? Now you can see what the leaf looks like. (Finishing up the example rubbing)

Daughter: Look it, a drawing! (Looking excitedly at the camera)

This interaction was typical for Darlene and her daughter throughout this and other sessions. She structured each step of the activity, explaining and demonstrating it to her daughter before they continued. She also participated during every step, either demonstrating and guiding for her daughter, collaboratively playing, or leading the activity herself. She expressed frequent examples of both supporting and

diminishing her daughter's choice and control. For example, before the interaction shown above, she allowed her daughter to pick which colors of crayons to use and which leaves to start with for the rubbings. At the same time, Darlene controlled the flow and structure of the activity and on several occasions prevented her daughter from using the materials herself, at least until she had seen the entire process. And although her daughter showed some signs of impatience, she was clearly excited by the end result and remained interested as the two continued making leaf rubbings. Similarly, during other sessions, Darlene often encouraged her daughter to wait to try something new until they talked about it or completed the current portion of the activity, and her daughter frequently seemed to hesitate to move on before getting directions from her mother.

Tanisha's Family

In contrast to Darlene, Tanisha was much more likely to likely to adopt a passive or supporting role during the sessions. Two thirds of the sessions with Tanisha and her child (activity boxes and family choice) were coded as child led and one third were coded as parent led (reading session). Tanisha's experience with her daughter and the making bubbles activity box provided a typical example of a child-led session, with fewer instances of Tanisha diminishing or supporting choice and control compared to other parents. During the session, Tanisha spent more time watching her daughter explore the materials than helping to guide or direct. At the outset, the two of them collaborated on mixing the bubble mixture ingredients and experimenting with blowing bubbles and making wands with the pipe cleaner. However, after about 5 minutes, the mother received several texts on her phone and at that point began to play a more passive role in the interaction:

Tanisha: That's getting big! (Watching her daughter blow bubbles in the bowl with a straw)

Tanisha: Okay, whoa!

Daughter: No, no, no. (Smiling)

Tanisha: Are you gonna keep blowing? (Smiling, the daughter uses her hands to pop all the bubbles)

Daughter: I'm gonna keep on going. (Blowing more bubbles into the bowl as Tanisha watches)

Daughter: Take a picture!

Tanisha: The tablet's over there.

Daughter: You go get the tablet and take a picture! (Both smiling as Tanisha goes to get the tablet and take a picture of her daughter with the bubbles)

From this point on, Tanisha took on more of an observational role, asking questions about what her daughter was doing, acting surprised, and letting her take the lead. She took pictures and videotaped her daughter blowing bubbles and then occasionally asked questions and made comments as her daughter transitioned into an imaginative cooking and potion-making game. Similarly, during the family choice session, Tanisha took her daughter on a walk to the local park and followed her daughter's lead as they talked about a variety of topics.

Other Families

Of the seven parents, Sabrina was most similar to Darlene in her parenting approach. Like Darlene, all of Sabrina's sessions were coded as parent led. Emily on the other was more similar to Tanisha, with half of the sessions (reading and activity boxes) coded as parent led, while the other two were coded as child led. For example, during the OMSI visit, Emily followed her daughter from one exhibit to the next, primarily watching and smiling from a distance and occasionally making a comment or asking a question. She seemed happy to follow her daughter to the next activity whenever she was ready, and the structure and flow of the overall experience was almost entirely determined by the daughter's choices and interests. Other parents were more likely to be coded as mixed leadership styles during the interactions. Across the families, the total number of instances of diminishing or supporting control ranged from 119 for Darlene (just under 30 per session on average) to 58 for Emily (14.5 on average per session), with other families falling within this continuum. Sabrina had an average of 24 instances per session, while Tanisha had an average of 20.

Re-engaging Children in the Moment

Related to the roles that parents assumed during the interactions, we also saw differences in how parents reacted when their children showed signs of interest loss or tried to change focus. In almost every session, children began the activities clearly excited and engaged. These were novel experiences and many mothers reported that children were not only excited by the new activities and materials but also the

chance to have special, focused time with their parents. Inevitably, however, there were times when children lost or changed their current interest focus. In coding moments of situational interest loss, we included instances of children becoming distracted, such as by a sibling or a passing ice cream truck; making a bid to shift the focus of an activity, such as wanting to move on to the next book or activity box; showing signs of disinterest, such as complaining that the book was too long or asking if they were done with the walk yet; and engaging in power struggles with their parents during which they became less focused on the activity and more on negotiating control. As might be expected with four-year-old children, these instances were not uncommon and parents often worked to reengage their children in the activities. The number of moments of situational interest loss ranged from 0 to 17 per session (6 on average), with the largest number of instances occurring during the reading session. [6]

Once we had identified moments of situational interest loss, we also explored how mothers responded during these moments and whether or not the children ultimately reengaged in the current focus. For each interest loss moment, we developed a coding framework to identify mother responses and outcomes. For this analysis, we grouped response strategies together that were more activity focused, including expressing interest in the activity, interpreting or explaining, personalizing, pointing out details, suggesting new possibilities, prompting physical participation, quizzing, and supporting choice and control. These were in contrast to more general reengagement strategies, such as asking or commanding children to continue with the current activity.

All of the mothers experienced moments of child situational interest loss during each of the sessions. However, how they responded, and how often children reengaged, varied widely. Some mothers always used at least one, and often multiple, activity-focused reengagement strategies, while other mothers used fewer or less activity-focused approaches. Similarly, some parents regularly reengaged their children in the current activity or session focus, while others were more likely to move on to the next focus area (e.g., activity box or exhibit) or end the session early.

Raymona's Family

Raymona was one of the parents that used a variety of strategies to help her daughter stay focused on the current activity, even when her daughter changed focus or expressed moments of situational

interest loss. For example, after playing with the bubble activity with her daughter for several minutes, Raymona got up to check on something in the kitchen. When she returned, her daughter asked if they could move on to the next activity:

Daughter: Mom, light is golden! (Pointing to the bubbles in the bowl)

Raymona: There's a light to it?

Daughter: Now it's green. You can make different kinds of…

Daughter: Can we do that art now, the blue one? (Pointing to the natural materials activity box as the mother returns from the kitchen)

Raymona: We haven't even gotten to see much about the bubbles. Here we go, what do we do with the string? (Pulling the length of string out of the bubbles activity box)

Daughter: Where do we put this? (Pushing the bowl of bubble solution to the side)

Raymona: You're done with this already? (Laughing) Let's try something else—I didn't even get to see if my star would work! (Referring to her star-shaped bubble-making tool)

Daughter: Oh, your star! I'm sorry. (Moving the bowl in front of her mother)

In the transcript above, Raymona reacted to her daughter wanting to try the second activity box by suggesting new possibilities (using the string), keeping the tone positive and light (laughing and showing surprise when her daughter wanted to move to the next activity), expressing her own interests and goals (trying out the star-shaped bubble wand she had made), setting expectations (insisting that they should try different things with each box), and being persistent (using multiple strategies to reengage her daughter). In this case, Raymona's daughter returned to the bubble activity, and the two of them ended up spending over 20 minutes building and testing bubble-making tools. In all 10 of the situational interest loss moments coded during the study, Raymona always used multiple, activity-focused reengagement strategies and her daughter reengaged with the current focus in each instance.

Emily's Family

Emily's daughter was coded for a similar number of situational interest loss moments during the study (eight). However, Emily used relatively few reengagement strategies, and no activity-focused ones, across all of these moments, and her daughter ultimately only reengaged or stayed with the current focus

about a third of the time. One of these instances occurred during the reading session. Emily and her daughter had been reading for several minutes when there was the sound of music outside the apartment:

Emily: "From top to bottom, inside and out, both friend and foe all ramble about…" (Reading and beginning to turn to the next page)

Daughter: Let me see, let me see. Another ice cream truck! (Getting up from the house where she and her mother had been reading)

Emily: There is another ice cream truck. Don't worry about it, honey.

Emily: [Name], we're reading! Come on. [Name], come on, please!

Emily repeatedly asked the daughter to return to reading and after several minutes, she got back on the couch. However, the daughter continued to look distractedly at her foot and out the window for the remainder of the session. Although most parents would likely struggle to keep their children focused on a book with the sound of an ice cream truck in the background, it is striking the different approach that Emily took to reengaging her daughter compared to Raymona. Emily primarily tried to ask or coax her daughter back to the couch, without referring to the book, modeling her own interest, or using another activity-focused strategy. Nonetheless, it was clear that Emily valued having her daughter continue to read the book, which the two of them ended up finishing despite the distraction.

Other Families

Other families varied in the types of strategies they used and the degree to which their children reengaged after moments of situational interest loss. Some parents, such as Sabrina, Raymona, and Darlene, almost always reengaged their children in the current topic or activity focus. Darlene, for example, experienced 21 instances of her child losing interest, becoming distracted, or wanting to change focus. Out of these instances, she was able to reengage her daughter about 71% of the time. She was also coded as using a variety of reengagement strategies, including 28 activity-focused strategies. Maddy and Tanisha, on the other hand, reengaged their daughters during about half of the situational interest loss moments, and Emily and Michelle about a third of the time. These parents generally used fewer reengagement strategies overall, and fewer activity-focused approaches. For example, across the sessions, Michelle's daughter was coded for 15 situational interest loss moments and during these her mother used

6 activity-focused strategies. Because situational interest is an important first step in interest development, these dynamics around interest loss moments may be connected to patterns of early childhood science-related interest trajectories. Helping children to reengage in a particular topic or activity may support movement to deeper levels of interest. On the other hand, allowing children to choose when and how they direct their interest may also be an important parenting strategy, as suggested by parents use of strategies for both diminishing and supporting children's choice and control described previously.

Discussion

This study documented the science-related interests of four-year-old girls from low-socioeconomic backgrounds and provided initial evidence of variation in parent-child interactions potentially linked to early childhood science-related interest development. Although the sample size was small, the intensive, in-depth video and interview data collected in multiple contexts over time allowed us to develop detailed descriptions of children's interests, their interactions with their parents, and mothers' reflections on these experiences. Building on prior research, the study also provided additional evidence that science-related interests do emerge and persist in early childhood and that parents from low-socioeconomic backgrounds have a variety of strategies and approaches, some shared across families and some unique, for fostering and supporting these interests in the moment and over time.

Early Childhood Science Interest Development

Researchers have struggled to define and measure interest and to provide detailed accounts for how interest develops over time (Renninger & Bachrach, 2015; Renninger & Hidi, 2011). Building on the four-phase model of interest development, in this study we identified a variety of emergent indicators of science-related interest. First, observing that all children in the study began the sessions highly focused and engaged with the session activities, we identified moments of situational interest loss, how mothers responded to these moments, and the outcomes of those responses. Second, we used the in-depth interviews to capture mothers' reports of child interests that were sustained beyond the specific sessions. Finally, we distinguished between two types of parent-reported sustained interests that were apparent in the interview data: (a) *focused* sustained interests, focused exclusively around the materials and activities

presented during the sessions, and (b) *broad* sustained interests, which extended beyond specific materials and activities to more general topics or practices.

Because we intentionally created situations that revolved around science topics and practices, we made the assumption in this study, which should be tested in future research, that the sustained interests reported by mothers would provide the foundation for longer-term interest in science topics and practices more generally. All of the reported interests did fall into the science concept categories used by Leibham and colleagues (2013) in their study of early childhood interest, including life science and nature (e.g., leaves, rotting logs, insects, animals and sea life, plants and trees) and Earth science (e.g., rocks and gems, bubbles, water and the ocean). Children's reported interests also intersected with practices of science, such as using scientific tools, experimenting and testing, observing and comparing, and learning about famous scientists and methods of scientific investigation (NRC, 2009; NGSS Lead States, 2013).

These emergent indicators of interest both align with and extend the four-phase model of interest development and provide a clearer understanding of how this model applies to early childhood. Our focus on situational interest loss during the sessions corresponds to the first phase of the model, triggered situational interest, defined as "a psychological state of interest that results in short-term changes in affective and cognitive processes" and is typically but not exclusively externally supported (Hidi & Renninger, 2006, p. 114). Our data highlight not only the importance of triggering situational interest, as occurred for all of the girls at the beginning of each session, but also the dynamics of temporary situational interest loss and reengagement (Gobert, Baker, & Wixon, 2015) throughout the experiences as mothers used different approaches to keep their daughters focused on the current activity. Similarly, we argue that the *focused* sustained interests reported by mothers align with the second phase of the model, maintained situational interest. This phase has been described as "a psychological state of interest that is subsequent to a triggered state, involves focused attention and persistence over an extended episode in time, and/or reoccurs and again persists" and is typically but not exclusively externally supported (p. 114). These girls exhibited, with their mothers' support, a tendency to focus on and re-engage with particular materials and activities multiple times over the course of several weeks or months.

Hidi and Renninger (2006) defined the third phase of interest development, emerging individual interest, as "a psychological state of interest as well as the beginning phases of a relatively enduring predisposition to seek repeated reengagement with particular classes of content over time" (p. 114). They also argued that emerging individual interest is typically but not exclusively self-generated and can be supported externally, including support for increasing knowledge and encouragement to persevere when difficulties arise. The mothers' reports of *broad* sustained interest observed in their daughters share many characteristics with this phase. In particular, broad sustained interests were characterized by reengagement with "particular classes of content over time," rather than specific activities or materials, and were often initiated and driven by the children themselves. Furthermore, when describing these interests, mothers often constructed narratives about connections with prior experiences and future opportunities for supporting and developing these interests, providing additional evidence that broad sustained interests may be indicators of longer-term, emerging individual interests related to science.

In summary, these three facets of early childhood science-related interest (reengagement in the moment, focused interests, and broad interests) provide a roadmap for researchers to continue to describe and explain how young children move through different stages of interest with their families and how these interests develop into long-term learning trajectories. As we describe next, they also provide opportunities to understand the factors that influence interest development at each stage.

Variation in Parent-Child Interactions

In addition to advancing the field's descriptive understanding of early childhood science-related interest development, we also identified critical areas of variation across families in the nature of parent-child interactions that are potentially linked to different interest development patterns. This study represents, to our knowledge, the first empirical investigation of the characteristics of parent-child interactions associated with young children's interest development. As noted previously, researchers have speculated on the variety of parenting behaviors and strategies that potentially influence interest development in early childhood, such as showing excitement and interest and answering children's curiosity questions. To date, however, no studies have documented specific variation among families,

especially in low-income communities, to shed light on the links between the nature of parent-child interactions and the development of early childhood science-related interests.

In this study, we found that parental engagement during the activity sessions ranged along several continuums related to mothers' communication of positive affect, their leadership styles, and their approach to reengaging children during moments of interest loss. Furthermore, although this qualitative investigation was not designed to examine causal relationships between the nature of parent-child interactions and children's developing interests, we did observe intriguing connections between these two facets of the data. Families that primarily reported only evidence of focused interests in their children, including Michelle, Tanisha, and Emily, were also generally characterized by a greater proportion of negative compared to positive expressions of affect during the interactions, more passive or support-oriented leadership styles, fewer activity-focused reengagement strategies, and fewer instances of successfully reengaging children in the current activity during moments of interest loss. Generally, the opposite was true for families that reported more evidence of broad interest in their children, especially for Maddy, Raymona, and Darlene, although there was considerable variation within each group. Interactions between parents and children within these families were more likely to be characterized by a greater proportion of expressions of positive effect, little to no expressions of negative affect, active or directive leadership styles, more activity-focused reengagement strategies, and more instances of successfully reengaging children in the current activity. Table 2 shows an example of how these patterns might be analyzed, although these comparisons were beyond the scope and focus of the current study.

Table 2. *Summary of coding results, by family*

		Affect		Leadership				Interest loss	
Name	Interest evidence	Positive instances	Negative instances	Parent led	Mixed	Child led	Diminish/ support	Re-engage	Strategies
Raymona	Broad	64 (16)	1 (0)	1	2	1	94 (24)	100% (10)	1
Darlene	Broad	31 (8)	3 (1)	4	0	0	119 (30)	71% (21)	28
Sabrina	Broad	21 (7)	1 (0)	3	0	0	72 (24)	71% (17)	13
Maddy	Broad	55 (14)	0 (0)	1	3	0	78 (20)	50% (8)	8
Tanisha	Focused	15 (5)	8 (3)	1	0	2	60 (20)	50% (12)	3
Emily	Focused	28 (7)	4 (1)	2	0	2	58 (15)	38% (8)	0
Michelle	Focused	38 (13)	6 (2)	1	1	1	50 (22)	27% (15)	6

Note. For positive and negative affect, total coded instances are shown, with the mean number per session in parentheses. For leadership, the number of sessions coded for each leadership pattern shown. For diminishing and supporting control, the total number of coded instances are shown, with the mean number per session in parentheses. For interest loss, the percent re-engagement is calculated as the number of coded instances out of the total number of situational interest loss moments for each family (for activity boxes and reading sessions only). Total number of activity-focused re-engagement strategies across all the sessions is also shown.

Although speculative, these differences suggest that the characteristics of parent-child interactions highlighted in our study may be important for supporting the transition from situational interest to emerging individual interest at this early age. Alexander and colleagues (2015) similarly focused on this transition and posited that through regular, ongoing interactions, parents help facilitate movement between these two stages (p. 10). It may be that how well parents are able to maintain triggered situational interest, including re-engaging children during moments of interest loss, and how they are involved with their children during these interactions can make a difference between children remaining in a stage of maintained situational interest or moving to a broader, more enduring emerging individual interest phase. Although clearly young children are predisposed to become interested in objects and phenomena in the world around them (IOM & NRC, 2012; NRC, 2000a, 2000b), parents likely play an important role in shaping the breadth, depth, and persistence of these interests (see also Falk et al., 2016). This may partially explain why children have been shown to be more likely to pursue interest areas and careers similar to those of their parents and caregivers (e.g., Dorie, Jones, Pollock, & Cardella, 2014).

It is important to note that although we believe some parenting strategies and approaches to parent-child interactions might better support early childhood science interest development compared to others, we make no claims about right or wrong parenting styles. Parenting is a highly cultural-specific

activity (Gutierrez & Rogoff, 2003; Rogoff et al., 2003), and research continues to show that there are many ways to raise children to become successful and productive members of society (National Academies of Sciences, Engineering, and Medicine, 2016; NRC, 2000a). Although interest development in preschool has been linked to a number of positive developmental and academic outcomes in kindergarten and beyond (e.g., Fisher et al., 2012; Hume, Allan, & Lonigan, 2016; Leibham et al., 2013; Neitzel, Alexander, & Johnson, 2017), it may be that some parenting strategies that support science interest development are not as well suited for promoting other early childhood development outcomes, and vice versa, and that some strategies are appropriate in specific cultural contexts but not others. Furthermore, we recognize that the data in this study represent only brief snapshots of these families lives and do not take into account life circumstances, daily events, and other contextual factors that influenced how parents and children engaged during each of the research sessions.

Implications for Future Research

In this exploratory study, our goal was to move beyond speculation and develop hypotheses for future research grounded in data, leveraging the strengths of naturalistic, qualitative research. The results provide a foundation for future investigations to understand the proximal and distal processes that shape early childhood science-related interest development, as well as the factors related to interest development more broadly.

Beyond testing the speculative links between parent-child interactions and interest development described above, this study also suggests a number of questions to be explored in future studies. For example, what are the long-term differences between children who develop focused and broad sustained interests related to science? We tracked interest development over approximately 2 to 3 months, but it is not clear how differences identified across families might persist and influence later development and behaviors. It may be that these two types of interest development patterns (focused and broad) represent different ways that children develop interests and that ultimately both can result in sustained individual interest pathways related to science.

Also, how do parenting strategies shift as children continue to develop emerging individual interests? In this study, we saw indications that highly active and directive parenting strategies may be

associated with broader extended interests on the part of children. However, in order to support further interest development, parents may need to shift the balance away from directive strategies and focus more on supporting agency, independence, and self-efficacy, aligned with the notion of dynamic and responsive scaffolding (R. Azevedo, Cromley, & Seibert, 2004; Vygotsky, 1978; Wood, 2001; Wood, Bruner, & Ross, 1976) and the changing needs of individuals at different stages of the four-phase model of interest development (Hidi & Renninger, 2006; Renninger & Hidi, 2011; Renninger & Su, 2012).

Finally, are the patterns identified in this study similar for preschool boys? Prior research has found differences between boys and girls in the focus of early childhood interests (e.g., Alexander et al., 2015; Alexander, Johnson, Leibham, & Kelley, 2008; DeLoache et al., 2007), the duration and trajectory of these interests (Alexander et al., 2012; Leibham et al., 2013), and how parents and caregivers respond to children's interests and preferences (Alexander et al., 2012). It is likely that certain proximal processes and contextual factors are universally important for both girls and boys, while others are more gender specific.

The study also leaves open many questions about how more distal factors, such as parenting beliefs about children's learning, relate to the proximal processes of parent-child interactions and, in turn, influence interest development at this age. Prior studies have identified positive correlations between parents' and caregivers' science-related interests, beliefs, and values and those of children (Andre, Whigham, Hendrickson, & Chambers, 1999; Frenzel et al., 2010; Tenenbaum & Leaper, 2003). Several longitudinal studies with preschool children have also indicated that parent and caregiver beliefs are associated with the development of sustained interests in young children (Johnson et al., 2004; Leibham et al., 2005). Although not reported in this article, our in-depth interviews with mothers highlighted areas of variation in parental beliefs that are also potentially linked to early childhood science interest development, including adults' own interests and enjoyment related to science activities, their beliefs about their roles as parents in supporting their children's interests, their awareness of their children's interests and different strategies for supporting interest development, and their reflective orientation as a parent (Pattison, 2014). Aligned with the bioecological model of human development, a critical next step for researchers will be to understand how these beliefs influence early childhood interest development

through specific proximal processes, and especially the ongoing interactions between parents and children. By identifying variations in parent-child interactions among families, we have identified three important targets for this research: parental expression of positive affect, parent involvement and leadership, and re-engaging children during moments of interest loss.

Conclusion

We now live in a world dominated by science and technology. In order for children and adults of all communities to be successful in school and life, they must develop science skills and learning dispositions. While efforts to support these goals often focus on older children, it is now recognized that the foundations of early science interest and learning begin even before children enter school and are supported by informal learning experiences with parents and caregivers. We hope this study provides another important step forward in our understanding of how science-related interests develop at this early age and how adults can support these processes. This is particularly important for individuals from low-income communities, who face multiple barriers to engaging with science throughout their lives. As the study highlights, families from low socioeconomic backgrounds are motivated to support their children's science learning and demonstrate a range of strategies for encouraging their children's interests. These findings suggest opportunities for helping families support their young children's developing science-related interests while still honoring diverse approaches to parenting (NRC, 2000a; Rogoff et al., 2003) and the unique and culturally situated beliefs, values, and realities within communities.

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Endnotes

[1] Throughout this article, we use the term "parent" broadly to refer to both biological parents as well as other adults, family members, and guardians that serve as the primary caregivers for their children. All the adult-child dyads that participated in this study included the children's biological parent. However, researchers have long recognized that many individuals beyond the biological mother or father can serve as significant adults and primary caregivers in children's lives (NRC, 2000a).

[2] Constructivist grounded theory, like many approaches to qualitative research (Patton, 2015), does not involve empirical testing of interrater reliability. Instead, the emphasis is on researcher interpretations through the exploration of the nuances of meaning and experience (Charmaz, 2006). Research findings, therefore, must be understood within the context of the researchers' perspectives and data analysis process.

[3] All the names used in this report are pseudonyms, chosen by the participants.

[4] Families are eligible to participate in the Head Start program if their household income is below 100% of the federal poverty line; they receive income-based public assistance, such as through Oregon's Temporary Assistance for Needy Families (TANF) program or the federal Supplemental Security Income (SSI) program; they are enrolling a foster child; or they are classified as homeless.

[5] Positive and negative affect codes did not include facial expressions, laughter, or other non-verbal indicators of affect because of the challenge of reliably interpreting these behaviors and the potential danger of cross-cultural misinterpretations. The terms "positive" and "negative" in this context refer to the valence of emotional signals, rather than inherent judgements about correct approaches to parent facilitation.

[6] For our analyses of the number of situational interest loss moments, outcomes, and parent responses, we only included the activity and reading sessions. During the OMSI visits, children often moved quickly from one exhibit to the next, especially at the beginning of the visits. This behavior created a large number of situational interest loss moments with little opportunity for parents to respond or try to reengage their children. During the family choice sessions, which were often nature walks, it was much more difficult to determine moments of situational interest loss, since the walks usually included a large number of small interaction moments, such as comments about plants and flowers at the side of the path, with little expectation for ongoing focus around any particular object or task.