HOME SCIENCE INTERACTIONS AND THEIR RELATION TO CHILDREN'S SCIENCE CORE KNOWLEDGE IN PRESCHOOL

by

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ABSTRACT

A limited body of work has examined the nature and scope of young children's science-related activities outside of the school context; and thus, there is little understanding or consensus regarding what the home science environment is comprised of (i.e., interactions, activities, resources) and how specific factors of the home science environment relate to children's science performance. The two primary goals of this study were to 1) examine the factor structure of home science interactions and 2) evaluate how these factors relate to the science core knowledge of young children from families with low incomes. Ninety-eight children (52 female) aged three to five years participated in the study. Approximately 61.42% of the children were White/Caucasian, 12.60% were Black/African American, 14.96% were Hispanic, and 11.02% were multiracial. Children were assessed on a measure of science core knowledge and parents completed a brief questionnaire on their home science interactions that included questions pertaining to both home science disciplinary core idea (DCI) engagement and home science and engineering practices (SEP) engagement. Findings revealed that although separating home science interactions into distinct DCI and SEP factors represented the data well, the best overall representation of home science interactions was a one-factor model including only home DCI engagement items. In addition, home DCI engagement was significantly predictive of children's science core knowledge above and beyond a large group of covariates, including the child's age, race/ethnicity, gender, and performance on math, executive function, and vocabulary tasks, as well as their parent's education. The findings of this study ultimately demonstrate that families' interactions about science core concepts are related to children's science knowledge.

INTRODUCTION

With growing concern surrounding science achievement in the U.S., a large emphasis has been placed on science instruction not only in educational standards and learning expectations for children grades K-12, but also into early experiences prior to formal school entry (Morgan et al., 2016). A growing body of evidence has examined factors that are related to young children's science performance and science achievement gaps in school, including child characteristics such as gender (Andre et al., 1999; Mantzicopoulos et al., 2008; Sackes, 2013; Steinkamp & Maehr, 1983), race/ethnicity (Morgan et al., 2016), and performance in other academic domains including math (Guo et al., 2015; Nayfeld et al., 2013), executive function (Bauer & Booth, 2018; Nayfeld et al., 2013), and language (Bauer & Booth, 2018; Zucker et al., 2016), as well as family characteristics, such as socio-economic status (SES; Guo et al., 2015; Sackes, 2013). Parent involvement in science learning in the home has also been linked to older children's (i.e., ages 10 and 15) science performance (Ho, 2010); however, no work has examined this relation with preschoolers. The home environment has been identified as an optimal context to provide rich early science experiences as parents can integrate science into everyday home activities with their young children (Bell et al., 2009; Greenfield et al., 2017). Thus, it is possible that differences in opportunities to learn about science in the home could relate to young children's science performance (Sackes et al., 2011). However, due to a limited body of work that has examined the nature and scope of young children's science-related activities outside of the school context, there is little understanding or consensus regarding what the home science environment is comprised of and how specific factors of the home science environment relate to children's science performance. Thus, the two primary goals of this study were to 1) examine the factor structure of home science interactions and 2) evaluate how specific factors of home science interactions relate to the science performance of young children from families with low incomes.

Importance of Science

Currently, the U.S. is experiencing fundamental educational reform to enhance children's science, technology, engineering, and math (STEM) learning (National Research Council [NRC], 2012). Much of the impetus for science education reform stems from concerning national trends in students' science achievement and motivation, which generally show that a large proportion of children are both underperforming in and are disinterested in science (Buckley, 2011; U.S. Department of Education, 2016). According to the 2015 U.S. National Assessment of Educational Progress (NAEP) only 38% of fourth graders, 34% of eighth graders, and 22% of twelfth graders were proficient in science (National Center for Education Statistics [NCES], 2015). With the small proportion of students proficient in science, it is not surprising that the U.S. scores substantially behind other countries in science achievement (Buckley, 2011). In addition to the majority of students exhibiting low performance in STEM subjects like science, 84% of high school seniors are disinterested in pursing STEM careers and degree programs post-graduation (U.S. Department of Education, 2016). These statistics are concerning because in order to keep up with the growing technological and economic demands of our society, it is imperative that the U.S. produces more STEM graduates (Hossain & Robinson, 2012). Further, producing well-educated STEM graduates is necessary to address major issues including climate change, disease and other health threats, conservation of resources, national security, trade, and more (Smithsonian, 2019). Having STEM capabilities is also important to be successful as the U.S. is a new-information-based and highly technological society (National Science Board, 2007). There are also shortages in the proportion of female and minority students who pursue STEM-related degrees and careers (Buckley, 2012; Burke & Mattis, 2007). These shortages ultimately raise concerns about the quality, quantity, and diversity of the future science and engineering talent (National Academy of Engineering [NAE], 2005; International Technology Education Association [ITEA], 2002). Thus, as students generally demonstrate low proficiency in science across grade levels and because many students face challenges with STEM based on demographic factors, efforts are needed to support STEM learning across students' demographics and ages.

A result of the concern surrounding these national trends is that a greater emphasis has been placed on STEM initiatives for schools in the U.S. (DeJarnette, 2012). One of the most dramatic changes can be seen in the creation of the K-12 Next Generation Science Standards (NGSS). The NGSS were developed by the collaborative effort of 26 states, the National Research Council (NRC), the National Science Teachers Association (NSTA), and the American Association for the Advancement of Science (AAAS), with the goal of creating more rigorous expectations for science and engineering for students K-12 (NGSS Lead States, 2013). Since their release in 2013, the NGSS have been implemented in several states and districts across the nation

(NGSS Lead States, 2013). In addition to a greater emphasis on STEM in the learning standards and expectations for children, several national foundations, including the AAAS and National Science Foundation (NSF) have promoted programs and initiatives that provide opportunities for the American youth to connect with STEM fields (DeJarnette, 2012).

Despite efforts to incorporate more rigorous expectations for science into the K-12 standards and national program efforts to connect children with STEM, significant gaps in children's science knowledge are already present prior to kindergarten entry and these gaps remain stable well into primary schooling (Morgan et al., 2016). These early gaps likely exist because there have been very few national efforts that have focused on science and engineering opportunities for preschoolers (Greenfield et al., 2009). Thus, the youngest of learners must be provided ample and equal opportunities for early science and engineering exposure in order to capture children's interest in STEM and to promote the development of early science skills (DeJarnette, 2012).

Science Learning in Preschool

The early childhood period has been identified as an optimal time in which to introduce science content as young children are equipped with the innate curiosity to explore the world around them (Jirout & Klahr, 2012). Notably, children are often regarded as "little scientists" due to their natural tendency to discover and assimilate information (Gopnik, 2012). Theoretical work suggests that with guidance and structure, children's curiosity can be raised, and their exploration can become more scientific (Worth, 2010). Further, this early period of exploration is an optimal time to provide children with accurate science content to expand on their current knowledge of the world and correct any misunderstandings they have (Duschl et al., 2006). Children enter preschool already building science knowledge (National Academy of Sciences [NAS], 2007) and when children learn about science in preschool, it is likely that they will gain a better and deeper understanding of science later on, as well as positive attitudes towards learning about science (Conezio & French, 2002; Eshach & Fried, 2005; Gerde et al., 2018). Further, early exposure to science can fuel excitement for children to learn about science and boost children's confidence and self-efficacy in their abilities to succeed in STEM courses later on (Dejarnette, 2012).

The Dimensions of Early Science

Young children's science knowledge is comprised of both a body of core content knowledge and the scientific inquiry processes by which children acquire the content knowledge (Zimmerman, 2000). Science core knowledge, formally known as knowledge of the disciplinary core ideas (DCIs), encompasses children's understandings of the four disciplinary areas of science, including life sciences, earth and space sciences, physical sciences, and engineering and technological applications of science (Bustamante et al., 2018; Greenfield et al., 2009; NAS, 2007; NGGS Lead States, 2013; NRC, 2012). The division of preschoolers' science core knowledge into these four domains was adopted from the science and engineering expectations for children K-12 as outlined in the NGSS. NGSS also contains expectations for children's science and engineering practices (SEPs), which are the inquiry processes children use to explore and develop their knowledge and understandings of phenomena within each of the domains (Greenfield et al., 2017). Although there are not expectations outlined for preschoolers in the NGSS, using the same conceptual framework to guide early learning ensures continuity between preschool and formal schooling (Greenfield, 2015).

Science Core Knowledge

Although the recognition of these four domains for preschoolers' science core knowledge is fairly new, extant evidence has demonstrated that young children learn about science prior to formal school entry in each of the disciplinary areas physics/mechanics (e.g., Baillargeon, 1995; Baillargeon et al., 1985; Bullock et al., 1982; Gelman & Lucariello, 2002; Kamii & DeVries, 1978; Krist et al., 1993), life sciences (e.g., Gelman, 2003; Gelman & Hirschfeld, 1999; Inagaki & Hatano, 2006; Keil, 2003; Lopez et al., 1997; Toyama, 2000), earth and space sciences (e.g., Nobes et al., 2003; Nobes et al., 2005; Panagiotaki et al., 2006; Schoultz et al., 2001; Siegal et al., 2004) and engineering sciences (e.g., Bustamante et al., 2018; Evangelou et al., 2010; Flannery & Bers, 2013; Fleer, 2000; Kazakoff et al., 2012). For example, Wang et al. (2018) found that four- and five-year-old children harness the invisible property of weight to solve causal problems. Further, the preschoolers consistently selected the correctly weighted object to produce the desired effects, including displacing a small object, balancing a scale, and building a stable tower (Wang et al., 2018). Another study found that preschoolers understood basic information about biological processes, like digestion (Toyama, 2000). The young children knew that plants and animals transform food and digest it in order for their bodies to use it (Toyama, 2000). Rochovská (2015) interviewed preschoolers about their understandings of various earth science concepts, including clouds, weather, rainbows, storms, and fog, and found that preschoolers are capable of providing definitions for these concepts and have basic understandings of their functions/purposes. Preschoolers have also been found to naturally engage in systems thinking, an engineering habit of mind, with various materials throughout their classrooms (Lippard et al., 2019). Systems thinking involves identifying and understanding the interconnectedness of materials and how parts of a system contribute to a whole (NAE & NRC, 2006). These studies demonstrate that young children start to develop a base of science core knowledge, even prior to formal school entry.

Science Practices

In addition to a body of core content knowledge, science also encompasses SEPs, which are the inquiry processes children use to explore the world around them and to construct science knowledge (Greenfield et al., 2017; NGSS Lead States, 2013). These practices include observing, asking questions, generating hypotheses and predictions, experimentation/testing of a hypothesis, summarizing/analyzing data to draw a conclusion, communicating discovery and process to others (verbally and/or in writing), and identifying a new question (Gerde et al., 2013). These processes are further defined by Gerde et al. (2013): observation occurs when children notice and gather information about the world around them. Next, a child generates a question based on an interest in something they have observed. Hypothesizing and predicting involve making a specific guess about the answer to the question they have posed. Experimentation occurs when children engage in an activity in order to evaluate their predictions. Children then draw conclusions based on what they found during their experiment. Finally, children can communicate their discoveries with other adults or children.

Scientific practices have been identified as a key element of early science learning (French, 2004; French et al., 2000) and are foundational for science in formal schooling (Fusaro & Smith, 2018). Early science learning is suggested to involve an interplay of both science practices and core knowledge (Zimmerman, 2000). Further, scientific practices are integral to rich science learning and underlie children's acquisition of science core knowledge (Gelman & Brenneman, 2004). Researchers suggest that when children use practices to learn about science concepts within the specific domains, they test hypotheses more often, which leads to restructuring of incorrect thinking and revisal of hypotheses (Koerber & Osterhaus, 2019). This further leads children to expand their understanding of science core concepts and in turn, experience gains in science core knowledge (Koerber & Osterhaus, 2019). When science instruction is rooted in inquiry-based techniques, children experience the greatest developmental gains (Howitt et al., 2011; Peterson & French, 2008; Inan et al., 2010). Further, Samarapungavan et al. (2011) found that when biological and physical content were taught in an inquiry-based curriculum, kindergarteners experienced significant gains in their science core knowledge. The kindergarteners who participated in the inquiry-based curriculum also significantly outperformed their peers, who participated in their school's regular curriculum, on an assessment of science knowledge (Samarapungavan et al., 2011). Another study conducted with kindergarteners showed that children's science practice skills significantly predicted and uniquely contributed to children's science core knowledge (Koerber & Osterhaus, 2019). Studies that have been conducted with secondary school students have also identified significant relations between students' inquiry engagement and their science core knowledge (Songer & Linn, 1991; Stathopoulou & Vosniadou, 2007; Stender et al., 2018). Thus, although engagement in DCIs and SEPs are both individually important for science knowledge construction, it is believed that when early science instruction involves both interactions about core concepts and uses science practices, children have the deepest, conceptually-connected understandings of science (Worth, 2010).

Factors Related to Science Performance

A large body of work has examined child-level factors that are related to science performance and achievement, including gender (Andre et al., 1999; Mantzicopoulos et al., 2008; Sackes, 2013; Steinkamp & Maehr, 1983), race/ethnicity (Morgan et al., 2016), and motivation and self-efficacy (Sun et al., 2012), for children of various ages. In addition, several studies have emphasized the critical contributions of home and parental characteristics on older students', primarily those who were in primary and secondary schooling, science performance and achievement (Perera, 2014). Of this work, studies have shown that SES (Sackes, 2013; Smith & Hausafus, 1998; Szechter & Carey, 2009; Tare et al., 2011), parenting styles (Smith & Hausafus, 1998; Szechter & Carey, 2009; Tare et al., 2011), parental attitudes toward education (Chen, 2001), parental attitudes toward science (Simpson & Oliver, 1990; Sun et al., 2012), and parent involvement in children's science learning (Ho, 2010; Ratelle et al., 2005; Smith & Hausafus, 1998; Szechter & Carey, 2009; Tare et al., 2011) are related to science performance. Parent involvement in science learning has been measured in several ways, including engagement in explanatory conversations (Tare et al., 2011), using "what if" questioning and eliciting predictions (Szechter & Carey, 2009), and the availability of science resources in the home, such as video games, magazines, books, newspapers, and television (Ho, 2010; Smith & Hausafus, 1998). A limited body of work has examined the relations of parental characteristics, like SES (Guo et al., 2015), to preschoolers' science performance and no work has examined the role of parent involvement in science learning in the home on preschoolers' science performance. One study showed that preschoolers demonstrate differences in their science performance based on SES, and more specifically, that those with families with higher SES perform better in science than those with families with lower SES (Guo et al., 2015). It is critical to examine the role of home science interactions on preschoolers' science performance as the home environment has been found to play an important role in children's development, learning, and overall school success (Collins et al., 2000; Morrison & Cooney, 2001), and has been found to exert an even stronger influence over academic outcomes than parental factors, like SES (Melhuish et al., 2008). As family-level factors, such as parent education, are related to preschoolers' science performance (Guo et al., 2015), it is likely that home science interactions are related to children's science knowledge over and above factors like SES.

The Home Learning Environment

Although parental factors such as income, education, and ethnicity have been commonly linked to children's academic outcomes (Adi-Japha & Klein, 2009; Kluczniok et al., 2013; Sammons et al., 2004), including science (Guo et al., 2015; Sackes, 2013), extant evidence has demonstrated that the home learning environment also exerts a strong influence over academic outcomes (Melhuish et al., 2008). The home learning environment encompasses the characteristics of the home setting, including the activities, attitudes, and resources, that are believed to enhance children's learning (Dearing & Tang, 2010; Yeo et al., 2014). The literature on the home learning environment has become more specialized to emphasize learning that is targeted by parents in three domains: literacy, mathematics, and executive function. Early literacy encompasses knowledge of the basic conventions of print, an ability to detect and manipulate language, and vocabulary, which are pertinent to the development of reading and writing (NELP, 2008). Early math involves the development of distinct, but highly related, subskills characterized by discriminating between sets of quantities, counting, linking numbers to quantities, and performing operations with verbal numbers (Krajewski & Schneider, 2009). Executive function is a set of distinct processes that help control and regulate attention and behavior (Miyake et al., 2000). A great breadth of evidence has demonstrated strong relations between both the home literacy environment (HLE; Burgess et al., 2002; Payne et al., 1994; Schmitt et al., 2011; Sénéchal & LeFevre, 2014) and the home math environment (HME; Anders et al., 2012; Baker, 2014; Hart et al., 2016; Kleemans et al., 2012; Napoli & Purpura, 2018; Niklas et al., 2016) with children's math and literacy outcomes. In addition, more recent work has demonstrated that the home executive function environment (HEFE) is a distinct factor of the home learning environment and is related to children's performance on executive function tasks (Korucu et al., 2019). Although the domain-specific home learning environments have been linked to preschoolers' performance in their specific domains, the relation between the home science environment and preschoolers' science performance has yet to be examined.

The Home Science Environment

Parents' involvement in children's science learning has often been linked to science achievement for studies that have used samples of older students (Ho, 2010; Ratelle, et al., 2005; Smith & Hausafus, 1998; Szechter & Carey, 2009; Tare et al., 2011). Parental involvement in older children's science learning has been found to occur in various ways, including engaging in explanatory conversations (Tare et al., 2011), using "what if" questioning and eliciting predictions (Szechter & Carey, 2009), participating in hands-on science projects and simple experiments, visiting libraries, science centers, and museums (Barton et al., 2001; Sun et al., 2012), supervising homework, purchasing science books, and encouraging children to watch science television programs (Ho, 2010; Sun et al., 2012). However, little empirical work has examined the home science environment of young children (Vandeermaas-Peeler et al., 2018). In addition, although home science experiences have been found relate to science achievement for older students, no work has examined if home science experiences are related to young children's science performance.

Few empirical studies have examined the home science environment of preschool-aged children (e.g., Gerde et al., 2021; Korpan et al., 1997). Findings from these studies regarding how often families engage in science experiences with young children have been mixed, with one study showing limited offerings of science in the home learning environment (Gerde et al., 2021) and another study showing a strong emphasis on science (Korpan et al., 1997). Korpan et al. (1997) developed and used the Community and Home Activities Related to Technology and Science

(CHARTS/PS) to examine families' engagement with science resources in the home and community. Their sample was comprised of middle-class families and they found a high prevalence of engagement in science-based activities in the home. Further, families reported engaging in reading and viewing television programs about science around 150 times per year for each activity type (Korpan et al., 1997). Families also participated in approximately 12 science community-based activities per year on average, with some parents reporting weekly activities or outings related to science (Korpan et al., 1997). Gerde et al. (2021) used the Home Science Interview (HSI; Van Egeren & Stein, 2012), an extension of the CHARTS/PS, to assess the types of science-related toys, play content, books and technology, and community resources Head Start families used to support their children's science learning and ultimately found that there were limited offerings for science in the homes of Head Start children. As the measures used to assess the home science environment inquired primarily about families' resources, it is possible that the discrepancy in findings between these studies was due to the nature of the home science measure.

Theoretical work (e.g., Greenfield et al., 2017) and educational texts (e.g., Bell et al., 2009; NAS, 2007) have suggested that early science experiences are not limited to one's access or utilization of resources, but rather that opportunities to learn about science emerge in everyday interactions with the surrounding world. Further, this work posits that the home science environment should not viewed in terms of its resources that provide science stimulation, but rather should be considered as a wide array of everyday activities and routines through which science learning can occur (Bell et al., 2009). A significant portion of science learning occurs in settings where the goal is not to teach or learn science (Bell et al., 2009). While some everyday activities are explicitly focused on learning science content (e.g., reading science books or watching science television shows), other activities that may not appear science-focused can offer rich opportunities to engage in science learning. For example, clean-up time can easily become a science experiment about the absorbency of different materials like sponges and paper towels (Greenfield et al., 2017). Some studies have suggested that families play an important role in children's science and technology learning because they observed families engaging in a high frequency of activities or using resources that could be associated with science learning (e.g., attending a museum); however, these studies do not provide evidence that any learning is actually occurring (Hall & Schaverien, 2001). Further, although families attend observatories or museums, they could simply be reading labels or gazing at an exhibit (e.g., Hilke, 1988), instead of engaging in rich interactions that involve science concepts or scientific inquiry. Thus, as opposed to examining families' access and usage of resources, like science television shows or museum exhibits, it may be more meaningful to inquire about the interactions families have regarding science and the practices they use to engage in science learning. In addition, home interactions are likely central to early science exposure and learning as language is suggested to be fundamental for early science knowledge construction (Eshach & Fried, 2005; Norris & Phillips, 2003; Pappas, 2006). Through language-based science interactions at home, children may hear and use science-relevant terms that are important for the development of their science knowledge and skills. Research further suggests children require specific science-relevant language to be able to construct knowledge about scientific concepts and to be able to communicate their understandings (Eshach & Fried, 2005). Previous work has also shown that science is more strongly associated with language than with other academic and cognitive domains (e.g., literacy, math, math language, and executive function; Westerberg, Litkowski, et al., 2021). Thus, interactions about science in the home may equip children with the vocabulary that is essential for understanding science concepts and for engaging in science practices.

DCI Engagement in the Home. As opportunities for science teaching and learning arise in unpredictable ways in everyday life, parents have the important role of scaffolding science learning into these everyday interactions (Bell et al., 2009). Further, adult support is necessary to build on children's natural curiosity and to help children construct science knowledge (Spaepen et al., 2017). Teachable moments about the different domains of science are embedded into the questions children ask as they gather information about how their surrounding world works, such as, "Where does the sun go at night?" (earth and space sciences) and "Why don't my shoes fit anymore?" (life sciences; Greenfield et al., 2017). As children question and make observations about their world, caregivers and other family members can help interpret their inquiries and guide them to learn about scientific topics (Gelman et al., 2004; Harris & Koenig, 2006; Harris et al., 2006). A parent can ignite their child's interest in a certain scientific domain by providing experiences and resources pertinent to phenomena within the domain (Chi & Koeske, 1983; Crowley & Jacobs, 2002). For example, searching for insects outdoors can pique interest in animal behaviors (life sciences) while launching toy cars down a racetrack can pique interest in speed (physical sciences). When given these rich opportunities to learn about scientific phenomena, children may also become "experts" in particular domains (Bell et al., 2009). For example, a child whose parent teaches them how to build model airplanes may learn a great deal about aerodynamics while a child who helps their parent tend a garden may learn a lot about biological cycles. Consequentially, when children are provided with these rich home science experiences, it is likely they will be more interested, motivated, and excited to learn about phenomena in the natural and physical world (Bell et al. 2009).

SEP Engagement in the Home. Although most of the research on children's scientific practices has been conducted in the preschool setting (e.g., Gelman & Brenneman, 2004; Gelman et al., 2009; Gerde et al., 2013; Howitt et al., 2011; Inan et al., 2010; Westerberg, Vandermaas-Peeler, et al., 2021), a growing body of work has demonstrated that children's scientific thinking can be fostered in informal contexts like museum exhibits (Ash, 2003; Callanan, 2012; Crowley et al., 2001; Falk & Dierking, 2000; Vandermaas-Peeler et al., 2015) and the early home environment (Strickler-Eppard et al., 2019; Vandermaas-Peeler et al., 2018; Vandermaas-Peeler et al., 2019). Observational studies conducted in museum settings have shown that parents and their young children co-construct meaning and solve problems through collaborative inquiry while interacting with an exhibit (Ash, 2003; Crowley et al., 2001; Fender & Crowley, 2007; Vandermaas-Peeler et al., 2015). In addition, parents have been observed encouraging their children to make more predictions and evaluate their reasoning more often when provided with inquiry guidance instruction (Vandermaas-Peeler et al., 2015). This finding has been replicated in the home environment as well; further, when parents were encouraged to engage in inquiry with their children during a range of home activities (e.g., cooking, going on a scavenger hunts for rocks, etc.), parents and children engaged in complex practices, including predicting and evaluating/experimenting (Vandermaas-Peeler et al., 2019; Vandermaas-Peeler et al., 2018). Although studies on the guided inquiry in the home and in museums provide a detailed picture of what parents and children do when parents are provided with inquiry instruction, little is known about spontaneous scientific thinking in everyday activity (Crowley et al., 2001; Fender & Crowley, 2007; Peterson, 2009). Thus, there is a need for studies to examine both natural, everyday parent-child DCI and SEP engagement in the home environment.

Critical Gaps in the Home Science Environment Literature

A major limitation of studies that have explored the home science environment is that they used home science measures with broad resource-based questions that are biased towards families with more resources (e.g., Gerde et al., 2021; Korpan et al., 1997). The CHARTS/PS, the measure used to assess the early home science environment in previous work, was designed to evaluate access to science resources, like books, toys, television, and computer games, which require families to have the monetary means to access these resources. Thus, families from higher SES backgrounds may respond that they engage in science more frequently as they are more likely to have access to these types of resources. Furthermore, using a home science environment measure with broad resource-based questions could be driving the measurement difference observed between families with more resources and families with less resources. This is problematic because the settings for everyday science learning vary a great deal depending on the particular family and family's surrounding cultural community (Bell et al., 2009). For example, although some families have regular exposure to living animals, such as through visiting the local nature center or zoo, other families may be limited to viewing pictures of animals in books or caring for pets (Bell et al., 2009). Families also differ in their access to different types of technology (e.g., television and computers), materials (e.g., toys, books), and community resources (e.g., museums, parks, nature centers, community gardens); thus, home science experiences can look different from family to family. When measuring the home science environment, we must consider the diverse range of activities in which science learning can occur. For instance, although families whose children attend Head Start may not have access to the materials inquired about through the CHARTS/PS, they may engage in science learning in everyday interactions. As this study is conducted with families with low incomes, it is important to note that the families may not frequently engage in conversations about science either, and this is because studies have shown that parents' SES is related to the amount of language they use with their children (Hart & Risley, 1995; Hoff, 2003, 2006; Huttenlocher et al., 1991). However, there is also evidence to suggest that wealth does not determine the frequency in which parents speak to their children and that parents can be active agents in their children's lives despite financial circumstances (Rindermann & Baumeister, 2015). Furthermore, although wealth may determine the science resources families have access to, it may not determine how often families have interactions about science.

Another limitation of previous work on the home science environment is that it has been explored broadly and has not been examined in terms of the early science dimensions – DCIs and SEPs. While the CHARTS/PS has items that correspond to children's science question-asking, no work has used these items to parse the home science environment into both practice-based and core knowledge-based interactions in order to understand how they relate to children's science performance. Inquiring about both science practice-based and core knowledge-based activities and interactions in the home science environment will better inform us about what early parent-child experiences with science look like and whether they are supportive of both core knowledge and practices. In addition, examining DCI-based interactions and SEP-based interactions in the home allows for the relations of these factors with children's science performance to be examined.

A final limitation of studies that have examined the home science environment for preschoolers (e.g., Gerde et al., 2021; Korpan et al., 1997) is that the relation between the home science environment and children's science performance has not been examined. Although studies with older students have linked home science interactions to science achievement (Ho, 2010; Ratelle, et al., 2005; Smith & Hausafus, 1998; Szechter & Carey, 2009; Tare et al., 2011), no work with younger children has examined this relation. Thus, although parents and their young children may be engaging in interactions about science, it is not yet understood if these activities in the home are associated with how children perform in science.

The Current Study

The two primary goals of this study were 1) to examine the factor structure of home science interactions by separating these interactions into factors of DCI-based and SEP-based interactions and comparing this two-factor model to a unitary factor model, and 2) to examine the relation between these factors and the science core knowledge of preschoolers from families with low incomes. Considering that early science learning opportunities can be embedded within a wide array of everyday interactions and routines (Bell et al., 2009), it is critical that the structure of these interactions is examined to uncover what they are comprised of and how they relate to children's science performance. There's some evidence to suggest that SEPs and DCIs are distinct dimensions of children's science learning and may independently contribute to science performance, but no work has empirically evaluated if they are distinct constructs. Although these components are suggested to contribute to the development of science knowledge most effectively when used together (i.e., practices as the mechanism through which science content is learned; Howitt et al., 2011; Peterson & French, 2008; Worth, 2010), each component distinctly represents a different dimension of children's science learning. Further, core knowledge is the body of knowledge of phenomena within the DCIs (Greenfield et al., 2009) and SEPs are the inquiry processes that give rise to this body of knowledge (Zimmerman, 2000). Given this distinction, it was first hypothesized that home science interactions would best be represented by a two-factor solution of a home DCI engagement factor and a home SEP engagement factor.

Parent involvement in their child's science learning has been linked to science achievement for studies that have used samples of older students (e.g., Ho, 2010; Szechter & Carey, 2009; Tare et al., 2011). Although no work has examined this relation for preschool-aged children, it is likely that parent-child science interactions in the home play an important role in the science knowledge children bring with them to preschool. Further, parents may assist their children in building science core knowledge through providing experiences and resources pertinent to phenomena within a core area of science (Chi & Koeske, 1983; Crowley & Jacobs, 2002). In addition, studies have shown that parents are capable of supporting their children's SEPs in home activities (Vandermaas-Peeler et al., 2019; Vandermaas-Peeler et al., 2018). Although DCIs and SEPs represent distinct dimensions of science learning, when science learning involves an interplay of both DCIs and SEPs, children develop the deepest understandings of science (Worth, 2010; Zimmerman, 200). Further, empirical work has shown that when science instruction is rooted in inquiry practices, children experience the greatest gains in their science core knowledge (Samarapungavan et al., 2011). Although engagement in practices by itself (i.e., not in a science context) or learning about science through a technique other than through SEPs (e.g., in a didactic manner) are both likely to be related to children's performance in science, it is likely that when parents incorporate both DCIs and SEPs into their science interactions with their children, children will have the deepest understandings of science, and thus, will exhibit the highest science performance. Thus, as early science experiences in the home likely contribute to children's interest, motivation, and participation in science learning (Bell et al. 2009), and based on the assumption that SEPs are integral to deep understandings of science core knowledge and support the acquisition of science knowledge (Gelman & Brenneman, 2004), it was hypothesized that DCI engagement in the home and SEP engagement in the home would both be related to children's performance on a science core knowledge assessment, and further, that there would be an interaction between DCI and SEP engagement, such that children whose parents embed both DCIs and SEPs into home science interactions would have the strongest performance on the science core knowledge assessment.

Method

Participants

One hundred twenty-five children from eight local Head Start centers participated in the study. Children were aged three to five years (M = 3.60 years, SD = 0.55 years) with 42.97% of the sample consisting of three-year-olds, 53.91% consisting of four-year-olds, and 3.12% consisting of five-year-olds. Roughly 47.66% of the children were female. Approximately 61.42% of the children were White/Caucasian, 12.60% were Black/African American, 14.96% were Hispanic, and 11.02% were multiracial. As the participating children attended Head Start centers, family incomes were either at or below the Health and Human Services Poverty Guidelines ($26,500 for a family of four) or the family met other Head Start eligibility requirements, such as experiencing homelessness or that the child was in foster care (Early Childhood Learning & Knowledge Center, 2020). If parents reported partner's education level, the higher level of education between both partners was used to represent parent education level. For education level, 10.24% of parents completed some high school, 42.52% had a high school diploma or GED, 33.86% completed some college, 6.30% had an associate degree, 5.51% had a bachelor's degree, and 1.57% had a master's degree.

Measures

Home Science Interactions

The questionnaire used in this study was created to capture the frequency in which parents engage in interactions about science with their children in the home environment. The questionnaire was based on research on the home literacy and numeracy environments that has used frequency surveys (LeFevre et al., 2009; Napoli & Purpura, 2018). Although other questionnaires regarding science opportunities exist, they inquire mostly about resources utilized in or outside of the home to enhance science learning (e.g., science television shows and books). Instead of inquiring about access to resources, parents were asked to indicate how often they engaged in conversations about science with their child in the past month (e.g., "In the past month, how often did you and your child talk about the weather?"). The home science interactions questionnaire has ten items. Seven items are dedicated to the frequency in which parents and their children talk about content relevant to each of the DCIs (two items for life sciences, two items for physical sciences, two items for earth and space sciences, and one item for engineering and technology) and three of the items capture how often parents and children engage in SEPs (one item for observing and questioning, one item for predicting, and one item for evaluating/testing). The items that measure SEP engagement in the home environment cover both basic and more advanced levels of the cycle of inquiry. Observing and questioning are considered basic levels of the cycle of inquiry as they are practices children commonly engage in, typically without requiring much scaffolding from a teacher/parent, and represent the initial steps of inquiry (Hollingsworth & Vandermaas-Peeler, 2017). Predicting and evaluating are more advanced practices, as they bring children's thinking full circle, typically require more scaffolding from an adult (Gerde et al., 2013), and are used to gain understanding of complex concepts (Gelman & Brenneman, 2004; Hollingsworth & Vandermaas-Peeler, 2017). Creation of the SEP items was informed by research that has examined parent-child usage of inquiry in the home environment (Vandermaas-Peeler et al., 2019; Vandermaas-Peeler et al., 2018) and at a museum exhibit (Szechter & Carey, 2009; Vandermaas-Peeler et al., 2016). Responses were recorded on a five-point Likert scale ranging from *never* (0) to *daily* (4). The complete list of items can be found in Appendix B.

Science Core Knowledge

The CIRCLE: Science & Engineering subtest (Zucker, et al., 2016) is one of the first validated measures of young children's science core knowledge. The CIRCLE has demonstrated high test-retest reliability ($r = .82$) as well as high convergent validity with the Preschool Science Assessment (PSA), which is a reliable and valid diagnostic measure of young children's science knowledge (Greenfield et al., 2011). The CIRCLE was used to assess children's knowledge in the physical sciences, life sciences, earth and space sciences, and engineering and technology. The CIRCLE takes approximately five minutes to administer and has 24 items. Children are administered all 24 items and are given one point for each correct response. The CIRCLE demonstrated strong internal consistency for the current sample ($\alpha = .80$).

Covariates

Seven covariates were included in each of the analyses. Child covariates included age, a dummy code for gender (0 = male, 1 = female), dummy codes for race/ethnicity (White, Black, Latino, and Other), and performance on math, executive function, and vocabulary tasks. Parent education was also included and was coded as a dichotomous variable (0 = no college, 1 = at least some college). Each of these variables have been found to relate to science performance. More specifically, studies have shown that children whose parents have more years of education perform better in science than children with parents who have fewer years education (Guo et al., 2015; Morgan et al., 2016; Sackes, 2013; Sackes et al., 2011). In addition, increases in age are associated with increases in science performance (Guo et al., 2015). Studies have also shown that male students typically outperform their female peers in science (Sackes, 2013; Quinn & Cooc, 2015). In addition, White/Caucasian students typically outperform their Black/African American and Hispanic peers in science (Morgan et al., 2016; Quinn & Cooc, 2015). Having higher executive function (Bauer & Booth, 2018; Nayfeld et al., 2013), vocabulary (Bauer & Booth, 2018; Guo et al., 2015; Nayfeld et al., 2013; Westerberg, Litkowski, et al., 2021; Zucker et al., 2016), and math (Guo et al., 2015; Nayfeld et al., 2013) skills is associated with higher science performance. The children's schools were not included as covariates as the intraclass correlation coefficient (ICC) for the analysis was small (-.032), suggesting that there was little systematic school-level variation for science performance.

Math. Children's math performance was assessed via The Preschool Early Numeracy Skills Test—Brief Version (PENS-B; Purpura et al., 2015), which is a 24-item task representative of the broad numeracy skills children are expected to learn in preschool and kindergarten. Specific areas of assessment include set comparison, numeral comparison, one-to-one correspondence, number order, identifying numerals, ordinality, and number combinations. The task takes approximately five minutes to administer, and children receive one point for each question they answer correctly. Testing is completed either when all items are completed or when a child responds to three consecutive problems incorrectly.

Executive Function. Executive functioning abilities were assessed via the Three-Dimensional Change Card Sort (3 DCCS; Deak, 2003; McClelland et al., 2014; Zelazo, 2006). During this task, a child is instructed to sort a deck of cards into boxes on three dimensions: shape (fish, bird, dog), color (red, blue, yellow), and size (large, medium, small). Children first complete three sections that each have six items and continue on to complete a fourth section if they score five or more points on the third section. During the fourth section, children are shown a card with a border and are instructed to sort on the basis of size when the card has a border, and to sort by color when the card does not have a border. Thus, the measure contains either 18 or 24 items.

Vocabulary. Vocabulary was assessed via the National Institutes of Health (NIH) Toolbox Picture Vocabulary Test (TPVT), which is a measure within the NIH Toolbox Early Childhood

Cognition Battery (Weintraubet al., 2013). The assessment is administered on a touchscreen monitor and children were presented with a single word (read aloud from the device) and four images of objects, actions, and/or depictions of concepts appeared on the screen. The device instructed the child to select the image that corresponded with the presented word. There were two practice trials prior to the start of the testing portion. The system used computer adaptive testing, meaning that items were administered to match each participant's ability level with increasing difficulty. Theta scores provided by the NIH Toolbox output were used in analyses.

Procedure

Consent forms and questionnaires were distributed to local Head Start centers and the forms were completed during the fall of the preschool year, before conducting assessments with the children. Written consent for participation in the study was obtained from the children's parents and school directors, and verbal assent was also obtained from the children, prior to starting assessments. Children were assessed on their science core knowledge, math, executive function, and vocabulary in the fall of the preschool year, during October through December. For the assessments, a team of researchers visited the centers during a typical school day and administered the assessments one-on-one in a quiet space or classroom area designated by the school directors or teachers. Each child was assessed for approximately 30 minutes at a time. On average, administration of the testing battery took about four 30-minute sessions to complete per child. Individuals who had either completed or were working toward completion of a bachelor's degree in human development, psychology, or speech/language and hearing sciences conducted the assessments. All testers completed four two- to three-hour training sessions in which they learned how to administer each of the assessments. Following training, testers were certified on each of the assessments to ensure proper administration of the assessments.

Analytic Plan

To evaluate RQ1, whether home science interactions could be separated into DCI-based and SEP-based interactions and activities, two CFAs with maximum likelihood estimation were conducted in Stata 16. First, a two-factor model was examined in which all of the items corresponding to activities and conversations about the DCIs (life sciences, earth and space sciences, physical sciences, and engineering and technology) were loaded onto a home DCI engagement factor and all of the items corresponding to the practices parents engage in with their children were loaded onto a home SEP engagement factor. Following this, the two-factor model was compared to a one-factor model in which all items were loaded onto a single home science engagement factor. The two models were compared on global model fit indices, including chi-square test, root mean square error of approximation (RMSEA), standardized root mean squared residual (SRMR), Tucker & Lewis Index (TLI), Comparative Fit Index (CFI), Akaike's information criterion (AIC), and Bayesian information criterion (BIC). A likelihood ratio test was also conducted to directly compare the models and ultimately determine which was the better-fitting model.

To evaluate RQ2, structural equation modeling analyses with full information maximum likelihood (FIML) were conducted in M*plus* 8 (Muthén & Muthén, 2017). In the first two structural equation models, children's science core knowledge was regressed onto the home DCI factor and covariates and then the home SEP factor along with covariates. In the third structural equation model, science core knowledge was regressed onto both factors and covariates. Finally, in the fourth structural equation model, both DCI and SEP engagement, and an interaction between these two factors, were examined as predictors of children's science core knowledge. In each of the structural equation model analyses, covariates included a dichotomous parent education variable, child age, dummy codes for child race/ethnicity, child gender, and performance on the math, executive function, and vocabulary tasks.

Results

Preliminary Analyses

Means, standard deviations, and ranges for covariates, science core knowledge, and scores for home DCI engagement and home SEP engagement are presented in Table 1. On average, parents reported only engaging in interactions pertinent to both DCIs (M = 1.67, SE = 0.84) and SEPs (M = 1.71, SE = 1.17) on a monthly to weekly basis. Internal consistency was strong for both the DCI items (α = .82) and SEP items (α = .81). Correlations among variables are presented in Table 2. The home DCI and SEP factors were significantly correlated (r = .62). However, both factors were not significantly correlated with children's performance on the science core knowledge assessment.

Primary Analyses

RQ1. Can Home Science Interactions be Separated into DCI-Based and SEP-Based Interactions?

A two-factor model was run in which all items corresponding to parent-child interactions about DCIs were loaded onto one factor and all items corresponding to interactions about SEPs were loaded onto a second factor. Goodness of fit indices were evaluated using Hu and Bentler's (1999) criteria, which suggest good model fit when SRMR values are less than .08, RMSEA values are less than .06, and CFI and TLI values are close to or greater than .95. The expected two-factor model was identified and fit indices for the model suggested adequate fit: $\chi^2(34) = 80.25$, $p < .001$, SRMR = .07, RMSEA = .11, CFI = .90, TLI = .87, AIC = 3647.97, BIC = 3734.90. In addition, a one-factor model was identified and fit indices for the model also suggested adequate fit: $\chi^2(35) = 109.43$, $p < .001$, SRMR = .08, RMSEA = .13, CFI = .84, TLI = .79, AIC = 3675.15, BIC = 3759.27. The models were compared using AIC and BIC, and the model with lower values (typically differences of ten or more) indicated a better fitting model (Burnham et al., 2011; Hu and Bentler, 1999; Kass and Raftery, 1995). Thus, the two-factor model demonstrated better fit. In addition, a chi-squared difference test was conducted to compare the two-factor and one-factor nested models and resulted in a significant difference ($\chi^2(1) = 29.17$, $p < .001$), again demonstrating that the two-factor model with distinct home DCI and SEP factors was the better-fitting model. Modification indices were used to provide statistical evidence for the unknown underlying relationships among items. An examination of modification indices indicated that one pair of correlated items, the second (*talk about the weather*) and third (*talk about plants*) items, yielded a large modification index (MI = 18.66). These items are likely correlated due to both relating to experiences or interactions parents and children have outdoors. These two items were correlated in a revised two-factor model and fit indices for this revised model demonstrated good fit: $\chi^2(33) = 62.01$, $p < .001$, SRMR = .06, RMSEA = .09, CFI = .94, TLI = .92, AIC = 3631.74, BIC = 3721.46. A revised one-factor was also run and fit indices for the model also suggested good fit: $\chi^2(34) = 84.45$, $p < .001$, SRMR = .06, RMSEA = .09, CFI = .94, TLI = .91, AIC = 3691.60, BIC = 3781.85. AIC and BIC values suggested again that the revised two-factor model was the better fitting model. A chi-squared difference test was also conducted to compare the revised two-factor and one-factor nested models and resulted in a significant difference ($\chi^2(1) = 22.44, p < .001$). Thus, overall, the two-factor model appeared to be the best representation of the factor structure of home science interactions. Factor loadings for the revised one- and two-factor models are presented in Table 4.

RQ2. Do the Home Science Interactions Factors Predict Children's Science Core Knowledge?

Four structural equation models with variables added in a stepwise fashion were run to address the second research question (results presented in Table 5; a supplementary model was also run with the full one-factor model and is presented in Appendix C). In the first structural equation model, only the home DCI factor and covariates were included as predictors of children's science core knowledge. In this first model, the home DCI factor significantly predicted children's science core knowledge ($\beta = .17, p = .040$). In the second structural equation model, only the home SEP factor and covariates were included as predictors of children's science core knowledge. However, in this model, the home SEP factor did not significantly predict children's science core knowledge ($\beta = .13, p = .117$). In the third structural equation model, both the home DCI and SEP factors, along with covariates, were included as predictors of science core knowledge. In this model, neither the home DCI factor ($\beta = .30, p = .153$) nor the home SEP factor ($\beta = -.14, p = .521$) significantly predicted children's science core knowledge. When the home DCI factor was added to the model with the home SEP factor, the direction of relation between the SEP factor and science core knowledge changed from positive to negative and the predictive validity for the home DCI factor increased, which is indicative of a suppression effect (Tzelgov & Henik, 1991). Further home SEP engagement suppressed (i.e., explained) irrelevant variance within home DCI engagement, therefore making the relationship between home DCI engagement and science core knowledge stronger (Gutierrez & Cribbie, 2019). To test the second part of the second hypothesis, whether there was a significant interaction between home DCI and SEP engagement, an interaction term was added in the fourth model. However, neither the home DCI factor ($\beta = .33, p = .129$), the home SEP factor ($\beta = -.15, p = .498$), nor the interaction ($\beta = -.07, p = .361$) significantly predicted children's science core knowledge. Thus, as SEP engagement only improved the model by explaining irrelevant variance in home DCI engagement, and because the factor itself was not associated with children's science core knowledge, a one-factor home environment solution, comprised solely of the home DCI engagement items, appeared to be a better representation of home science interactions.

Supplementary Analyses

A separate CFA of home science interactions was conducted using only the home DCI items (i.e., home SEP items were dropped). The model demonstrated strong fit: $\chi^2(13) = 27.23$, $p = .012$, SRMR = .06, RMSEA = .09, CFI = .95, TLI = .91, AIC = 2567.50, BIC = 2629.54. Both the AIC and BIC were significantly lower for this model than for any of the models from the primary analyses, suggesting that a one-factor model including only home DCI items was the best-fitting model overall.

Discussion

The purpose of this study was to examine the factor structure of home science interactions, and to examine the relations between the factors and preschoolers' science core knowledge. This study extends the literature on the home science environment as it is the first study to date to examine the relation between the home science engagement and preschool-aged children's science performance. Although home science interactions initially appeared to be best represented by a two-factor SEP and DCI solution, when both factors were included as predictors of science core knowledge in the same model, it was revealed that the SEP factor acted as a suppressor, and although the factor explained irrelevant variance in home DCI engagement, the SEP factor itself was not associated with children's science core knowledge. Further analysis revealed that a one-factor solution using only the DCI items was the best representation of home science interactions for the current sample. Home DCI engagement was found to predict science core knowledge above and beyond a strong group of covariates, including the child's age, gender, race/ethnicity, their parent's education, and their performance on math, executive function, and vocabulary tasks. In contrast, home SEP engagement, as measured in the current study, and an interaction between home DCI and SEP engagement was not found to predict science core knowledge.

The Factor Structure of Home Science Interactions

Current educational standards for science education (e.g., NGSS) and research on early science learning (Gelman & Brenneman, 2004; Worth, 2010; Zimmerman, 2000) depict science as being represented by distinct but related dimensions, including DCIs and SEPs. Further, children's science knowledge is thought to be comprised of both a body of core knowledge and the scientific practices by which children acquire core knowledge (Zimmerman, 2000). This study examined whether these dimensions were both represented in home science interactions. It was predicted that interactions about science would factor into conversations about science core concepts (e.g., animals, mass, planets) and engagement in practices (e.g., asking questions, making predictions), and the results revealed that a two-factor DCI and SEP solution represented home science interactions better than grouping these items together as a single factor. This finding further supported that these are likely distinct types of interactions in the home. However, after further examination, it was revealed that a one factor solution comprised of only the DCI items was a better representation of home science interactions. This is likely due to measurement issues with the SEP items. Although research has long emphasized inquiry practices to be important for children's developing science knowledge (Gelman & Brenneman, 2004; Peterson & French, 2008; Worth, 2010), different practices have been emphasized across the literature and across state-level science early learning standards. As we do not have a clear depiction of what practices are most appropriate and important for early childhood, it is not surprising that measuring these practices has been a challenge for the field (Greenfield, 2015).

In addition, in the current study, engagement in DCIs and SEPs in the home was measured using a scale that inquired about interactions. As interactions are language-based, it is possible that this scale was more effective at measuring DCI engagement than SEP engagement. Language has been suggested to be critical for children's developing science knowledge within the DCIs (Eshach & Fried, 2005; Norris & Phillips, 2003; Pappas, 2006). In addition, children's performance on assessments of science knowledge (e.g., CIRCLE: Science & Engineering Subtest – Zucker et al., 2016; *Lens on Science* - Greenfield & Penfield, 2013; Preschool Science Assessment [PSA] - Greenfield et al., 2011) have been found to be highly correlated with assessments of language (Bauer & Booth, 2018; Guo et al., 2015; Nayfeld et al., 2013; Westerberg, Litkowski, et al., 2021; Zucker et al., 2016). Thus, asking parents to report how often they have interactions about science core concepts may be an effective way to measure the frequency of their usage of language that is critical for children's developing science knowledge. However, measuring home engagement in SEPs is more challenging as practices correspond to the procedural or "doing" part of science, and simply asking parents about the frequency in which they engaged in practices may not capture this engagement well. Further challenges and suggestions for measuring home SEPs are discussed below.

Home DCI Engagement

To date, little has been known about how young children's families, particularly those with low SES, support early science learning at home (Gerde et al., 2021). Theoretical work has suggested that home science interactions play an important role in the science knowledge children build prior to school entry (Chi & Koeske, 1983; Crowley & Jacobs, 2002) and that rich home science experiences can enhance children's interest, motivation, and excitement to learn about phenomena in the natural and physical world (Bell et al. 2009). However, to date, the relation between parental involvement and science achievement has only been examined for older students (e.g., Ho, 2010; Ratelle, et al., 2005; Smith & Hausafus, 1998; Szechter & Carey, 2009; Tare et al., 2011), thus, this study is the first to examine this relation for preschool-aged children. The findings of this study revealed that the interactions parents have with their children about the four DCIs, such as having conversations about plants, animals, weight, weather, planets, and the make-up of objects, are positively related to their children's science core knowledge. To construct science core knowledge at home, parents provide their children with experiences and opportunities to learn about phenomena within a DCI (Chi & Koeske, 1983; Crowley & Jacobs, 2002). For example, parents and children may classify animals while examining footprints on a nature walk (life sciences) or may talk about the appearance of stars while examining the night sky (earth and space sciences). Through the provision of these experiences, parents assist their children in developing expertise within specific DCIs (Bell et al., 2009). These findings ultimately reveal that even before formal schooling, parents can assist their children in constructing science knowledge.

Home SEP Engagement

Contrary to what was hypothesized, we did not find evidence that home SEP engagement, as measured in the current study, was related to children's performance on the science core knowledge assessment or that there was a significant interaction between home DCI and SEP engagement. It is possible that SEPs were more challenging for parents to report on for several different reasons. First, it may have been easier for parents to identify their interactions about science concepts and their usage of science language in their daily routines and activities than to identify their engagement in practices. Further, the SEP items on the survey may not have aligned with the types of exploration and scientific thinking these parents engaged in, in the home setting.

Although SEPs have been identified as a critical dimension for rich science learning and underlie children's acquisition of science core knowledge (Gelman & Brenneman, 2004), different SEPs have been emphasized in both the literature on early science learning (e.g., Callanan, 2012; French et al., 2000; Gelman & Brenneman, 2004; Gerde et al., 2013; Vandermaas-Peeler et al., 2018; Zimmerman, 2000) and across state-level science early learning standards. In addition, although studies have shown that parents are capable of supporting various SEPs in home activities when they receive explicit inquiry guidance instruction (Vandermaas-Peeler et al., 2019; Vandermaas-Peeler et al., 2018), little is known about parental guidance of SEPs in everyday activities (Crowley et al., 2001; Fender & Crowley, 2007; Peterson, 2009). Thus, the SEPs included in the current items may not have covered the SEPs that parents often engage in with their children in the home environment. In a recent report, when parents were asked to define what science is for children, the parents often talked about their children's curiosity and their questions that arise during everyday routines (Silander et al., 2018). In the current study, parents reported higher frequencies of their children making observations and asking questions as compared to testing/retesting ideas and predicting/guessing. Question-asking may have been the only SEP in the survey that actually occurred frequently in the home environment. In future work, more items that inquire about the types of questions children and parents ask should be built out to further examine the relevance of questions for home science interactions. In addition, including more items about question-asking could have better depicted the SEP factor of home science interactions and could have made it a stronger factor.

Second, parents' beliefs about the importance of the science interactions items could have influenced their reporting. Parents have been found to believe that providing factually correct information to their children is key to promoting science learning, and they tend to not be aware of the importance of the practice-based components of science, such as noticing, talking about, and exploring the things that children wonder about and experience in their everyday lives (Silander, 2018). Thus, it is possible parents viewed their interactions about DCIs as instances where they provided their children with factual information about science concepts and phenomena, and they may not have believed that the SEP items were important to report on. Future work should examine the role of parental attitudes on home science interactions.

A third possible reason for why a significant relation between home SEP engagement and science core knowledge was not observed, and for why home SEP engagement acted as a suppressor for home DCI engagement, could be due to the small number of SEP items included in the home survey. Furthermore, the survey items may not have measured home SEP engagement as well as expected. Although the survey items covered practices that are commonly coded for in studies that have examined parent-child engagement in practices in informal settings (Szechter & Carey, 2009; Vandermaas-Peeler et al., 2019; Vandermaas-Peeler et al., 2018; Vandermaas-Peeler et al., 2016), this may not encompass the full range of SEPs that families would possibly use within the home setting. The items used within the survey measured only a few of the practices that have been identified in national standards for K-12 science education (e.g., National Science Education Standards [NSES]; NGSS). Practices not inquired about in the survey include developing and using models, analyzing and interpreting data, using mathematics and computational thinking, engaging in argumentation from evidence, and obtaining, evaluating, and communicating information (NRC, 2012). Thus, a future direction for this work is to build additional items for the home science interactions questionnaire, especially for home SEP engagement. With a larger and more encompassing bank of science practice items, future work can examine whether there would be an association between home SEP engagement and children's science performance.

Finally, it is important to note that SEP engagement was found to act as a suppressor for home DCI engagement. Although the suppression effect of home SEP engagement on home DCI engagement was not expected, it is still important to report and interpret this effect. Further, most researchers have refrained from identifying or interpreting suppression effects when they have occurred in their studies due to these effects being difficult to theoretically explain (Gutierrez & Cribbie, 2019). There are two possible interpretations for the observed suppression effect. First, it is possible that home SEP engagement is a true suppressor for home DCI engagement and explains irrelevant variance in home DCI interactions. However, replication studies are further needed to determine if home SEP engagement is a true suppressor (MacKinnon et al., 2000). Secondly, the suppression effect could have been observed due to a Type 1 error. Thus, future studies should examine whether this suppression effect replicates with a larger sample.

Limitations and Future Directions

The home science interactions questionnaire used in this study was designed to overcome some of the limitations of previous work that has examined the home science environment. Further, studies that have begun to examine the home science environment have primarily used resource-based measures (e.g., HSI, Van Egeren & Stein, 2012; CHARTS/PS, Korpan et al., 1997), which may have limited the information yielded regarding what science opportunities are available in the home by limiting the responses of families who did not have access to science resources and privileging those who did. In addition, other work that has examined the home science environment has used open-ended survey questions to identify how parents supported learning in each of the domains, but ultimately found that parents struggled to identify what the specific domains entail (Silander et al., 2018). Thus, to build on suggestions for work to more clearly understand how families support early science (Silander et al., 2018), this study used non-resource-based detailed questions (with examples embedded) to inquire about early home science interactions. In addition, the questionnaire included items for both DCI and SEP engagement, instead of asking about science engagement broadly. Despite these strengths, there are also limitations with this study, and in particular with the home science interactions measure.

First, the home science interactions questionnaire used a small number of items for both home DCI and SEP engagement (7 items and 3 items, respectively). Although each DCI (i.e., physical sciences, life sciences, earth and space sciences, and engineering and technology) was covered in the DCI engagement items, only a couple of items were used to indicate each core area. Additional items should be created to cover more content within each of these core areas of science because science learning opportunities in the home can occur in a wide array of everyday activities and routines (Bell et al., 2009). For example, in regard to physical science, some children may have more interactions about speed if they play with cars while other children may talk more about weight and other properties of objects if they build with blocks. Thus, building out additional DCI engagement items may provide families with more options to portray how they engage in science learning at home. In addition, as previously discussed, more SEP items should be created to reflect all of the SEPs as currently conceptualized in the most recent national guidelines for science education – the NGSS. The questionnaire also covered only two of the three dimensions of the NGSS three-dimensional model for science learning – DCIs and SEPs. Crosscutting concepts (CCCs) are the third dimension and are domain-general ideas that are suggested to connect learning across the disciplinary areas of science and also provide children with tools that can enrich their core knowledge and their utilization of science and engineering practices (NRC, 2012). The home science questionnaire developed for this study did not include items for CCC engagement as studies have examined only a few CCCs for preschoolers (e.g., cause and effect, Alvarez &

Booth, 2016; Bauer & Booth, 2018; systems thinking, Lippard et al., 2019). Future work should create items for CCC engagement to further examine the structure of home science interactions and to determine if all three dimensions are represented in the home during the preschool period.

Secondly, data were collected from a relatively small sample of families who all had low incomes. Although the questionnaire was purposively designed to not inquire about science resources and only interactions due to the nature of the sample, the results supported previous research conducted using resource-based measures (e.g., Gerde et al., 2021) in that there were low frequencies of science interactions in the home environment. Additional items that inquire about both families' science interactions and families' access to science resources should be used. Studies conducted with older students have found that parental involvement in science learning can occur in various ways. Beyond guiding their children to engage in practices such as explanatory conversations (Tare et al., 2011) and using "what if" questioning to elicit predictions (Szechter & Carey, 2009), involvement has also been found to include hands-on science projects and simple experiments, visiting libraries, science centers, and museums (Barton et al., 2001; Sun et al., 2012), supervising homework, purchasing science books, and encouraging children to watch science television programs (Ho, 2010; Sun et al., 2012). In addition, for studies conducted with samples with higher SES, parents have reported frequently accessing and using science resources, including reading and viewing television programs about science and participating in science community-based activities (Korpan et al., 1997). Future work should assess the home science environments of an economically diverse sample using a questionnaire with items pertaining to both science interactions and resources in order to examine if families differ in their access to science resources based on their SES. Gathering information regarding the home environments of families with diverse SES is an important perquisite to developing home science interventions that work for a diverse set of families.

Third, responses to the home science questionnaire were recorded using a rating scale which indicated the frequency of interactions. Although the survey provides information regarding the types of science interactions families have in the home environment and how often these interactions occur, the responses are not indicative of the quality of the science interactions. Opportunities for science teaching and learning arise in unpredictable ways in everyday life and parents have the important role of scaffolding science learning into these everyday interactions (Bell et al., 2009). Parents can build on their children's natural curiosity to help construct science knowledge (Spaepen et al., 2017). However, families may differ in their abilities to assist their children in constructing science knowledge. Further, although families may frequently have interactions regarding plants or animals, they may differ in the extent to which they explore life sciences phenomena during these interactions. For example, one parent may ask their child questions about where an animal lives or about what the animal eats while another parent may ask their child about the color of the animal. Future work should use qualitative data collection techniques, such as observation, to examine how families differ in their abilities to assist their children in constructing science knowledge.

Fourth, data were collected concurrently, thus it was not possible to examine the potential contributions of the child to the home science interactions. Certain child factors may also contribute to the frequency and types of science interactions that occur in the home in addition to parental factors. For example, some children may be more interested in certain science phenomena than others. One child may frequently elect to play with cars and thus interactions with family members may involve more physical phenomena, such as speed or fiction, while another child may prefer to play outdoors and thus interactions with family members may involve earth and space phenomena, such as weather patterns. Children have also been found to exhibit differences in their inquisitiveness (i.e., tendency to ask questions), and this is in turn is related to differences in problem-solving abilities, which are both SEPs (Fusaro & Smith, 2018). Thus, children may vary in how often they ask scientific questions in the home environment which in turn influences how often parents would provide science-relevant information to answer these questions. In addition, parents may differ in how often they encourage their children to engage in SEPs based on their child's abilities to engage in SEPs, like asking questions and constructing solutions for problems. Future work should examine the potential bidirectional associations between home science interactions and factors like children's science preferences and their science performance.

Finally, the measure used to assess science core knowledge, the CIRCLE: Science & Engineering Subtest (Zucker et al., 2016), only measures children's knowledge within the four DCIs (life sciences, physical sciences, earth and space sciences, and engineering). This measure does not assess children's abilities to engage in the SEPs. It is possible that SEP engagement in the home may have related to children's science performance had the measure been able to account for children's SEP abilities in addition to their science core knowledge. Currently, there are limited offerings for assessing early science and there are very few measures that assess science holistically (Greenfield, 2015). There is a critical need for future work to develop measures of children's SEP abilities. The creation of more comprehensive science assessments will permit the relations of home DCI and SEP engagement with children's science core knowledge and practices to be examined.

Conclusion

This study contributes to a small, emergent body of work on the early home science environment and extends this literature by examining whether home science interactions could be represented by a two-factor DCI and SEP solution, and by examining the relation between home science interactions and preschoolers' science performance. Although separating home science interactions into distinct DCI and SEP factors represented the data well, the best overall representation of home science interactions was a one-factor model including only home DCI engagement items, and this may be due to challenges with effectively measuring home SEP engagement. In addition, home DCI engagement was significantly predictive of children's science core knowledge above and beyond a large group of covariates. The findings of this study ultimately demonstrate that what parents do in the home to support early science learning is associated with their children's science knowledge. A deeper understanding of the home science environment is necessary to understand how preschoolers' science learning may be promoted in the home setting.

Table 1. Descriptive Statistics for Key Study Variables

Variable	*N*	*M or %*	*SD*	Min	Max
Age	125	4.30	0.63	3.17	5.26
Female	125	49%			
White	125	61%			
Latino	125	14%			
Black	125	13%			
Other	125	11%			
Parent Education	125	38%			
TPVT	98	-6.21	1.77	-10.30	-1.92
DCCS	92	9.40	4.97	2.00	22.00
PENS-B	102	5.86	4.90	0.00	18.00
Home DCI	125	1.67	0.84	0.00	3.71
Home SEP	125	1.71	1.17	0.00	4.00
CIRCLE	95	15.85	4.50	5.00	24.00

Note. Parent Education = has had at least some college (0 = no college, 1 = some college); TPVT, NIH Toolbox Picture Vocabulary Test; DCCS, Dimensional Change Card Sort; PENS-B, Preschool Early Numeracy Scale–Brief Version; Home DCI, home engagement in the science and engineering disciplinary core ideas; Home SEP; home engagement in science and engineering practices; CIRCLE, CIRCLE: Science & Engineering subtest.

Table 2. Correlations Among Key Study Variables

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Age	-												
2. Female	.10	-											
3. White	.05	-.04	-										
4. Latino	-.05	-.04	$-.51^{***}$	-									
5. Black	-.11	-.04	$-.48^{***}$	-.16	-								
6. Other	.06	.11	$-.44^{***}$	-.15	-.14	-							
7. Parent Education	-.17	.05	-.01	-.09	-.01	.14	-						
8. TPVT	$.55^{***}$	$.28^{**}$	$.25^{*}$	-.16	$-.28^{**}$	.06	-.06	-					
9. DCCS	$.25^{***}$	.01	.05	-.10	-.05	.06	-.01	$.48^{***}$	-				
10. PENS-B	$.63^{***}$	.08	.08	-.10	-.06	.04	-.12	$.56^{***}$	$.57^{***}$	-			
11. Home DCI	.00	-.07	.15	-.15	.00	-.08	-.03	$.21^{*}$	.08	$.20^{*}$	-		
12. Home SEP	.06	.03	-.04	-.07	.02	.09	-.01	.15	.10	.18	$.62^{***}$	-	
13. CIRCLE	$.56^{***}$	.07	$.22^{*}$	-.19	$-.22^{*}$	.09	-.10	$.60^{***}$	$.46^{***}$	$.61^{***}$	.20	.16	-

Note. TPVT, NIH Toolbox Picture Vocabulary Test; DCCS, Dimensional Change Card Sort; PENS-B, Preschool Early Numeracy Scale–Brief Version; Home DCI, home engagement in the science and engineering disciplinary core ideas; Home SEP; home engagement in science and engineering practices; CIRCLE, CIRCLE: Science & Engineering subtest.

* $p < .05$
** $p < .01$
*** $p < .001$.

Table 3. Fit Indices for the Models of the Structure of Home Science Interactions

Model	x^2	*df*	CFI	TLI	RMSEA	SRMR	AIC	BIC	x^2 dif[a]
One-Factor	109.43	35	.84	.79	.13	.08	3675.15	3759.27	-
Two-Factor	80.25	34	.90	.87	.11	.07	3647.97	3734.90	29.17*
Revised One-Factor	84.45	34	.94	.91	.09	.06	3691.60	3781.85	-
Revised Two-Factor	62.01	33	.94	.92	.09	.06	3631.74	3721.46	22.44*

Note. $N = 125$. CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = root mean square error of approximation; SRMR = standardized root mean square residual; AIC = Akaike's information criterion; BIC = Bayesian information criterion.

[a]Chi-square difference tests involved comparison of model in the row to the model in the row directly above.

* $p < .001$.

Table 4. Standardized Factor Loadings for the Two-Factor and One-Factor Models

Item	Science and engineering disciplinary core ideas	Science and engineering practices	Broad home science interactions
1. Talk about planets, stars, or outer space	.61	-	.57
2. Talk about the weather	.72	-	.67
3. Talk about plants	.54	-	.52
4. Talk about animals	.63	-	.56
5. Talk about what objects are made of	.69	-	.66
6. Compare the weights/masses/heights/densities of objects	.65	-	.65
7. Use tools like scales, magnifying glasses, telescopes, binoculars, cameras, or thermometers	.55	-	.55
8. Observe, describe, and ask questions about what is happening in their environment	-	.78	.70
9. Test and/or retest ideas to find the best answer to a question	-	.72	.65
10. Ask your child to predict/guess what might happen when trying something new	-	.81	.78

Note. All items significantly loaded onto each factor.

Table 5. Results of the Structural Equation Models Predicting Science Core Knowledge

	Model 1			Model 2			Model 3			Model 4		
Variable	*B*	*SE*	*β*	*B*	*SE*	*β*	*B*	*SE*	*β*	*B*	SE	*β*
Age	1.51	0.80	0.22	1.41	0.80	0.20	1.57	0.81	0.22	1.67*	0.80	0.24*
Female	0.35	0.62	0.04	0.26	0.63	0.03	0.38	0.61	0.04	0.33	0.60	0.04
Latino	-1.21	0.81	-0.11	-1.34	0.82	-0.12	-1.16	0.79	-0.10	-1.04	0.80	-0.09
Black	-2.01*	0.95	-0.16*	-2.03*	0.97	-0.16*	-1.95*	0.95	-0.16*	-1.97*	0.94	-0.16*
Other	0.06	0.95	0.00	-0.08	0.98	-0.01	0.16	0.93	0.22	0.18	0.93	0.01
Parent Education	-0.49	0.63	-0.06	-0.52	0.64	-0.06	-0.47	0.63	-0.05	-0.42	0.63	-0.05
TPVT	0.51	0.31	0.20	0.56	0.30	0.22	0.49	0.30	-0.10	0.43	0.31	0.17
DCCS	0.07	0.07	0.08	0.07	0.07	0.08	0.06	0.07	0.07	0.06	0.07	0.07
PENS-B	0.28***	0.08	0.30***	0.28***	0.08	0.30***	0.28***	0.08	0.30***	0.28***	0.08	0.31***
Home DCI	1.00	0.54	0.17*				1.84	1.40	0.30	1.98	1.42	0.33
Home SEP				0.52	0.33	0.13	-0.58	0.91	-0.14	-0.62	0.92	-0.15
SEP*DCI										-0.40	0.43	-0.07

Note. $N = 95$. TPVT, NIH Toolbox Picture Vocabulary Test; DCCS, Dimensional Change Card Sort; PENS-B, Preschool Early Numeracy Scale–Brief Version; Home DCI, home engagement in the science and engineering disciplinary core ideas; Home SEP; home engagement in science and engineering practices; CIRCLE, CIRCLE: Science & Engineering subtest.

* $p < .05$

** $p < .01$

*** $p < .001$.

APPENDIX A. BACKGROUND QUESTIONNAIRE

Family Background

1. What is your child's race/ethnicity **(circle all that apply)**?

White	Hispanic/Latino	Black/African American
Asian	American Indian/Alaska Native	Middle Eastern/North African
Native Hawaiian/Pacific Islander	Other (please specify):_______	

2. Language(s) spoken at home ___________________________________

3. Child's primary language _____________________________

4. Child's age **(circle one):** 3 4 5

5. What is your highest level of education? **(circle one)**

8th Grade or Less	Some High School	GED
High School Diploma	Some College	AA/AS Degree
BA/BS Degree	MA/MS	Doctoral/Postgraduate Degree

6. If applicable, what is your spouse/partner's highest level of education? **(circle one)**

8th Grade or Less	Some High School	GED
High School Diploma	Some College	AA/AS Degree
BA/BS Degree	MA/MS	Doctoral/Postgraduate Degree

APPENDIX B. HOME SCIENCE INTERACTIONS QUESTIONNAIRE

In the past month, how often did you and your child engage in the following? ***Circle the number in the appropriate box.***

	Never	1 – 3 times a month	About once a week	2 – 5 times per week	Daily
1. Talk about planets, stars, or outer space (e.g., "Do you think the moon has bumps and holes, or is it smooth?" or "Saturn has rings.")	0	1	2	3	4
2. Talk about the weather (e.g., "There are a lot of clouds! Do you think it will rain?" or "What do you need to wear when it is cold outside?")	0	1	2	3	4
3. Talk about plants (e.g., "What do plants need so that they can grow?" or "We should water our tomatoes every day.")	0	1	2	3	4
4. Talk about animals (e.g., "I wonder where elephants sleep." Or "Where does an octopus live?")	0	1	2	3	4
5. Talk about what objects are made of (e.g., I think this block is made of wood." Or "This tower is made of sticks and glue.")	0	1	2	3	4
6. Compare the weights/masses/heights/densities of objects (e.g., "The apple feels heavier than the lime." Or "The ducky floats but the block sinks. Why do you think that happens?")	0	1	2	3	4
7. Use tools like scales, magnifying glasses, telescopes, binoculars, cameras, or thermometers (e.g., "Let's take a picture of the trees." Or "The thermometer says 81 degrees. Do you think that is hot or cold?"	0	1	2	3	4
8. Observe, describe, and ask questions about what is happening in their environment?	0	1	2	3	4
9. Test and/or retest ideas to find the best answer to a question?	0	1	2	3	4
10. Ask your child to predict/guess what might happen when trying something new?	0	1	2	3	4

APPENDIX C. RESULTS OF THE BROAD ONE-FACTOR MODEL PREDICTING SCIENCE CORE KNOWLEDGE

An alternative structural equation model was also run in which all of the home science interactions items (i.e., both DCI and SEP items) were loaded onto a broad home science interactions factor, and children's science core knowledge along with covariates were regressed onto this single factor. The results indicated that the broad home science interactions factor was not significantly predictive of children's science core knowledge (β = .14, p = .076). Thus, grouping all of the items together did not predict children's science knowledge, providing further support for the separation of the items into distinct factors. However, a one-factor model comprised of only the DCI items was found to fit the data better than separating DCIs and SEPs into two distinct factors. Thus, the one-factor DCI model is the preferred model overall.

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