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Understanding Early Childhood Engineering Interest Development as a Family-Level Systems Phenomenon: Findings from the Head Start on Engineering Project

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Keywords

interest development, early childhood, preschool, science and engineering, qualitative case study, family learning, systems theory, Head Start, diversity and equity

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Understanding Early Childhood Engineering Interest Development as a Family-Level Systems Phenomenon: Findings from the Head Start on Engineering Project

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Abstract

There is growing recognition that interest is critical for engaging and supporting learners from diverse communities in engineering and other science, technology, engineering, and mathematics (STEM) topics. Although interest research has historically focused on older children, studies demonstrate that preschool-age and younger children also develop persistent, individualized interests in different objects, activities, and topics and that these early interests have important implications for ongoing learning and development. Unfortunately, there is relatively little research on engineering learning in early childhood and almost no work specific to the concept of interest. To begin to address this need, we conducted in-depth case study research with 15 English- and Spanish-speaking families and their preschool-age children participating in a family-based engineering education program through a local Head Start organization. Using systems theory to conceptualize interest development as involving the whole family, the study documented how both children and parents developed engineering-related interests through the program and explored the characteristics of and shifts in these interest systems. The qualitative, cross-case analysis highlighted three aspects of family-level interest development that varied across families and over time: (1) parent awareness, knowledge, and values; (2) family re-engagement with engineering activities; and (3) family use of the engineering design process. Shifts were also observed in a subset of the families that potentially signal movement toward deeper, sustained levels of engineering-related interest.

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Introduction

Despite a wide range of initiatives and programs focused on broadening participation in engineering, there continue to be demographic groups and communities that are underrepresented in the field, including women and people of color. Certainly, some progress has been made. In 2016, women accounted for nearly 21% of bachelor's degrees awarded in engineering and Hispanic/Latino graduates accounted for 11.5%, while 10 years prior the percentages were 19.5% and

7.8%, respectively (National Science Board [NSB], 2018). However, there is still a tremendous amount of work to do, as these percentages are well below the representation of these groups in the general population—with women at 50.8% and Hispanics/Latinos at 16.3% (NSB, 2018). Engineering education researchers, as well as researchers from other science, technology, engineering, and mathematics (STEM) education fields, have theorized a range of complex and interconnected factors involved in this persistent challenge of underrepresentation, including: decisions about specific courses along an academic trajectory (Wigfield & Eccles, 2000); the perceived alignment of potential career paths, values, and identity (Eccles, Barber, & Jozefowicz, 1999); the power of stereotypes associated with different professions (Cheryan, Master, & Meltzoff, 2015); and the realities of an unwelcoming educational context or workplace (Berdahl & Moore, 2006; Cortina, Kabat-Farr, Leskinen, Huerta, & Magley, 2013).

In addition to these factors, there is growing recognition that *interest* is critical for engaging and supporting learners from diverse communities in engineering and other STEM topics (Harackiewicz, Smith, & Priniski, 2016; Renninger & Hidi, 2016). Interest, both as we experience it in the moment and over time, motivates us to develop new knowledge and skills and use these as a foundation for further learning (Renninger & Hidi, 2011; Renninger & Su, 2012; Silvia, 2006). In this way, interest can be seen as a central organizer for all aspects of learning, connecting disparate experiences into coherent pathways that take on a life of their own as we come to see ourselves, and be recognized by others, as individuals with particular interests (Renninger & Hidi, 2016; Renninger, Nieswandt, & Hidi, 2015).

Interest research has historically focused on older children. However, growing evidence demonstrates that preschool-age and younger children also develop persistent, individualized interests in different objects, activities, and topics and that these early interests have important implications for ongoing learning and development (Ainley & Ainley, 2015; Leibham, Alexander, & Johnson, 2013). For example, negative early experiences with engineering and design can lead to inaccurate perceptions about what engineering is and who engineers are that can be extremely difficult to correct (Knight & Cunningham, 2004; Nauta & Epperson, 2003). In contrast, positive early learning experiences with engineering can provide young children with opportunities to participate in meaningful design-focused interactions (Cardella, Svarovsky, & Dorie, 2013; Dorie, Cardella, & Svarovsky, 2014, 2015; Svarovsky, Cardella, Dorie, & King, 2017, 2018), which can in turn lead to increased and sustained levels of engineering interest and engagement (Pattison & Ramos-Montañez, 2020; Pattison et al., 2018). Unfortunately, compared to other domains of STEM, there is relatively little research on engineering education and learning in early childhood and almost no work specific to the concept of interest.

In this article, we provide a first step to addressing these gaps within the context of a family-focused early childhood engineering education program for low-income English- and Spanish-speaking families. Launched in 2015, the Head Start on Engineering (HSE) project is an ongoing research–practice collaborative led by TERC in partnership with Mt. Hood Community College (MHCC) Head Start, University of Notre Dame, and the Oregon Museum of Science and Industry (OMSI) and focused on simultaneously understanding and supporting engineering-related interest development in early childhood (Pattison et al., 2017). For the work described in this article, we spent two years conducting in-depth case study research with HSE program participants to understand how both children and parents (defined broadly)[1] developed engineering-related interests through the program and beyond. In this article, we provide an overview of the theoretical framework that emerged, present research evidence of the family as an interest development system, and discuss implications for both research and practice.

Engineering in Early Childhood

In recent years, there has been an increased focus on introducing young children to STEM as a way of cultivating early interests and understandings that ultimately contribute to broader participation in the STEM fields (Immordino-Yang, Darling-Hammond, & Krone, 2018; McClure et al., 2017; National Science Teachers Association, 2014). However, while there is substantial research around early childhood mathematics (e.g., Phillipson, Gervasoni, & Sullivan, 2016; Zippert & Rittle-Johnson, 2020) and a growing body of literature around early childhood science (e.g., McClure et al., 2017; Silander et al., 2018), early childhood engineering continues to be the focus of only a few studies (e.g., Dorie et al., 2014; Svarovsky, Wagner, & Monica, 2018).

By taking a more longitudinal view of broadening participation in engineering, it is clear that pathways to engineering careers often begin well before the first year of college (Lent, Brown, & Hackett, 1994; Wigfield & Eccles, 2000). This recognition, fueled in part by the increasing inclusion of engineering topics in state and federal standards for K–12 education (Foster, 2009; Moore et al., 2014; National Academies of Sciences, Engineering, and Medicine [NASEM], 2020) and the increasingly broad uptake of engineering curriculum packages such as Project Lead the Way and Engineering is

[1] We use the term "parent" to refer to the primary adult caregiver or caregivers in a child's life, whether or not those adults are the child's biological parents.

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Elementary, has motivated research studies that examine the teaching and learning of engineering for pre-college students (Cunningham, 2018; Cunningham et al., 2020; National Academy of Engineering & National Research Council, 2009). Beyond the classroom, research on engineering and design-based learning experiences for young people within informal learning or out-of-school contexts (National Research Council [NRC], 2009) has also been on the rise, particularly with the rapid growth of the Maker movement beginning in the mid-2000s (Martin, 2015). Key studies from this body of literature have explored how design-based experiences can help young people develop their STEM interests and identities (Calabrese Barton & Tan, 2018; Kang et al., 2019), engage with complex design thinking (Martin, 2015), and participate in collaborative learning within the family and other social groups (Brahms & Wardrip, 2014).

The growing emphasis on K–12 engineering education is based in part on the increasing evidence that helping students develop meaningful connections to engineering at a young age can greatly impact their academic and professional trajectories. By the time children are in elementary and middle school, their beliefs and interests related to engineering are already solidifying. Youth, especially girls, and their parents tend to have low levels of interest in engineering and negative or limited perceptions of the engineering field. In one poll, only 5% of girls and 24% of boys between the ages of 8 and 17 indicated interest in an engineering career (American Society for Quality, 2009; Hill et al., 2010). Youth and their parents often underestimate their abilities in engineering and STEM (Frome, Alfeld, Eccles, & Barber, 2006; Herbert & Stipek, 2005; Lloyd, Walsh, & Yailagh, 2005; Tenenbaum, 2009), leading to inaccurate beliefs about the likelihood of success within engineering fields. Both prospective studies with youth and retrospective interviews with scientists and engineers emphasize how STEM-related interests develop in childhood, through support from family and friends (Crowley, Barron, Knutson, & Martin, 2015; Maltese, Melki, & Wiebke, 2014). These studies highlight the importance of STEM engagement and interest development in early childhood—interests that, as leading theories of occupational choice articulate, become increasingly central to decisions about classes, college majors, and careers (Eccles et al., 1999; Lent et al., 1994).

Interest Development

In our work, we focus particularly on how young children and their families build interest in the topic and practices of engineering, and how this interest motivates ongoing learning and engagement. We conceptualize interest as both the spark of emotion we feel when we are excited or compelled to engage with something in a particular moment, as well as the more enduring motivation to re-engage with a topic of interest that we may begin to associate with who we are as a person (e.g., "I'm someone who likes to watch birds and is interested in birding") (Hidi & Renninger, 2006; Renninger & Hidi, 2011). As described below, we also extend this definition to think about the whole family as an interest development system. Similar to other aspects of early childhood development (NASEM, 2016; NRC, 2000; Vygotsky, 1978), we assume that families develop interests related to specific topics or practices together, with adults and children continually influencing each other's interest development in different ways (Broderick, 1993; Crowley et al., 2015; Malin, Cabrera, & Rowe, 2014).

Interest in Early Childhood

Interest is a central facet of STEM learning for both older and younger children. Decades of research show that *interest* is a primary motivator of human behavior, a critical factor driving long-term engagement with science and engineering, and a central component to successful learning (Renninger & Hidi, 2011; Renninger et al., 2015; Renninger & Su, 2012). Interest triggered in a particular moment sets the stage for the development of more enduring individual interests (Hidi & Renninger, 2006), which extend beyond a specific context to shape attitudes and self-perceptions (Alexander, Johnson, & Kelley, 2012; Bathgate & Schunn, 2016; Leibham et al., 2013), drive knowledge and skill building (Barron, Martin, Takeuchi, & Fithian, 2009; Jansen, Lüdtke, & Schroeders, 2016), guide choices about science and engineering engagement inside and outside of school (Azevedo, 2015; Bathgate & Schunn, 2016; Gottfried et al., 2016), and ultimately influence career decisions (Boucher, Fuesting, Diekman, & Murphy, 2017; Tai, Liu, Maltese, & Fan, 2006).

We now know that children's interests develop early, in preschool and even before, including engineering- and science-related interests (DeLoache, Simcock, & Macari, 2007; Mantzicopoulos, Patrick, & Samarapungavan, 2008). These interests, in turn, are associated with concurrent play behaviors and preferences (Renninger & Leckrone, 1991; Rowe & Neitzel, 2010), as well as early math, reading, and literacy skills (Doctoroff, Fisher, Burrows, & Edman, 2016; Malin et al., 2014; Rowe & Neitzel, 2010). They also motivate ongoing family engagement, as when a child develops an area of expertise and parents respond by offering new resources, providing encouragement, and learning about the topic themselves (Ainley & Ainley, 2015; Crowley & Jacobs, 2002). Subsequently, as children move into elementary school, early interests predict emergent math skills (Fisher, Dobbs-Oates, Doctoroff, & Arnold, 2012), vocabulary and literacy development (Baroody & Diamond, 2016; Hume, Allan, & Lonigan, 2016), science-related self-concept and knowledge (Leibham et al., 2013), and classroom engagement (Neitzel, Alexander, & Johnson, 2016, 2017). However, despite the growing body of research correlating these interests with learning outcomes, we still know very little about the developmental trajectory of

STEM-related interests in early childhood or the processes underlying the emergence and development of interests at this age, especially related to the topic of engineering.

Not surprisingly, many researchers have speculated on the importance of parents and families in this process. Studies have documented the ways that parents facilitate and support their children's learning, many of which have been hypothesized to lead to interest development. For example, parents provide learning resources and experiences that create opportunities for sparking and extending children's interests (Ainley & Ainley, 2015; Barron et al., 2009), including engaging in scientific and engineering activities (NRC, 2009; Silander et al., 2018), and can inspire children through their own interests and passions (Bergin, 2016; Crowley et al., 2015). Parents also provide support when their children become focused on a particular activity or topic, such as when a child develops an area of expertise and parents offer encouragement, identify new resources, or learn about the topic themselves (Crowley et al., 2015; Crowley & Jacobs, 2002). During parent–child interactions, parents facilitate learning in a variety of ways that may support interest development, including providing explanations (Callanan & Jipson, 2001; Fender & Crowley, 2007), eliciting and responding to children's questions (Callanan & Oakes, 1992; Chouinard, Harris, & Maratsos, 2007), focusing and maintaining children's attention and engagement (Pattison, 2014; Pattison & Dierking, 2018; Pursi & Lipponen, 2017), and modeling and reinforcing children's natural curiosity (Ainley & Ainley, 2015; Schmelzkopf, Greer, Singer-Dudek, & Du, 2017). Beyond these hypothesized mechanisms, however, there is little direct evidence of the ways that parents and families are involved in interest development at this age.

Theorizing Interest as a Family-Systems Phenomenon

In operationalizing engineering-related interest development in early childhood, we expand on traditional, psychological accounts, which focus on what interests look like for individuals and how they motivate behavior and engagement. Specifically, we seek to account for the ways that interest development involves the whole family. To do this, we draw from systems theory (Broderick, 1993; Bronfenbrenner, 1979; Cox & Paley, 1997; Sameroff, 2009; Zuiker, Anderson, Jordan, & Stewart, 2016) to conceptualize how complex systems (like families) work, the dynamics and relationships that define these systems, and the implications of these system characteristics for understanding early childhood interest development. We begin by describing the more traditional perspective on interest and its limitations and then move to the development of a systems perspective on early childhood interest development.

Within the fields of education and psychology, interest is generally understood as a motivational variable that includes both cognitive and affective components, has a physiological and neurological basis, and, unlike other more general psychological dispositions or temperaments, such as achievement motivation, is always specific to a topic, object, or activity (Renninger & Hidi, 2011; Renninger et al., 2015). Most researchers distinguish two types of interest: (1) situational interest, as an emotional response to a particular activity or situation and (2) individual interest, as a more enduring aspect of motivation that leads to ongoing re-engagement and is increasingly self-supported and self-recognized (Hidi & Renninger, 2006; Renninger et al., 2015; Silvia, 2006). The four-phase model of interest development (Hidi & Renninger, 2006; Renninger & Hidi, 2011) maps these two aspects along a continuum, from *triggered and maintained situational interest* to the more enduring *emerging and well-developed individual interest*. Through this process, the positive emotion of interest becomes linked to a constellation of related constructs, including knowledge, values, skills, and awareness, all of which are influenced by new interest-related experiences and, in turn, motivate further engagement (Hidi & Renninger, 2006; Renninger & Su, 2012).

Despite the utility of this model and its broad adoption (Bell et al., 2019; Renninger & Hidi, 2016), scholars have increasingly argued for the need to expand conceptualizations of interest beyond their traditional psychological roots (e.g., Azevedo, 2011; Hedges & Cooper, 2016; Pattison et al., 2016). Recent work has critiqued the four-phase model in a variety of ways, including its focus on new interests sparked by novel experiences, rather than connections between evolving interests and prior experiences (Azevedo, 2018; Chesworth, 2016; Hedges & Cooper, 2016), and its assumption that interests are specific to a single topic or activity, such as science, rather than part of a more complex and interrelated set of goals, preferences, and social connections (Azevedo, 2015; Blankenburg, Höffler, & Parchmann, 2016). Scholars have also advocated expanding traditional notions of interest to accommodate sociocultural perspectives, such as funds of knowledge (Chesworth, 2016) and ecological perspectives on learning and development (Barron, 2006).

Systems Perspective on Family Interest Development

In our work, we have attempted to contribute to this broader understanding by applying a family-systems perspective to the study of interest development in early childhood (Broderick, 1993; Pattison et al., 2016, 2017, 2018). Systems theory and systems perspectives have long been applied to the study of families (Haefner, 2014; Jaskiewicz, Combs, Shanine, & Kacmar, 2017; White, Kline, & Martin, 2015), as well as understanding and supporting families in other fields such as therapy and health care (Bowen, 1966, 1978; Brown, 1999; Haefner, 2014; Johnson & Ray, 2016; Kitzman-Ulrich et al., 2010). However, the idea of the family as a dynamic system has still been slow to be adopted in some traditions, such as developmental psychology and early childhood education (Cabrera, Fitzgerald, Bradley, & Roggman, 2014; Christian, 2006; Cox & Paley, 1997).

Nevertheless, a systems perspective is foundational to early childhood development (Broderick, 1993). Researchers have long known that the central driver of development at this age is the reciprocal, back-and-forth interactions between children and their primary caregivers (Bronfenbrenner, 1979; NASEM, 2016; NRC, 2000; Sameroff, 2009). Parents and caregivers facilitate and scaffold children's cognitive, social, and emotional development (NRC, 2000; Vygotsky, 1978), while at the same time adapting and learning themselves based on feedback from and shared experiences with their children (Knafo & Galansky, 2008; Pattison, 2014; Sameroff, 2009). In fact, recent studies highlight how it can often be difficult or impossible to determine the directionality of influences among family members (Hume, Lonigan, & McQueen, 2015; Martin, Ryan, & Brooks-Gunn, 2013).

Systems theory, based on the study of complex adaptive systems from fields such as physics, ecology, and computer science (Davis & Sumara, 2006; Horn, 2008; Lemke & Sabelli, 2008), provides a powerful lens for accounting for these reciprocal relationships. According to Zuiker and colleagues (2016), "a system can be defined as a dynamic network of relationally interdependent agents…whose coordinated interactions lead to self-organized, holistic patterns, processes, and properties" (p. 83). Systems involve dynamic, interdependent connections among system elements that are not reducible to simple, mechanistic, or linear cause-and-effect relationships. Furthermore, the properties and behaviors of the system itself are more than the sum of the individual parts, emerging from the dynamic relationship among system components (Cox & Paley, 1997; White et al., 2015; Zuiker et al., 2016). Even cognitive processes assumed to reside within our heads likely exhibit these dynamics, being distributed across elements of the environment and the social and cultural systems in which we live (Hutchins, 2000).

We draw from the perspectives of a variety of systems researchers (Broderick, 1993; Bronfenbrenner, 1979; Cox & Paley, 1997; Davis & Sumara, 2006; Hutchins, 2000; White et al., 2015; Zuiker et al., 2016) to guide our approach to studying family interest development. Using systems theory to expand on the four-phase model of interest development (Hidi & Renninger, 2006), the team defines the family interest development system as *parents' and children's interrelated predispositions (stated and enacted) to reengage with a focus of interest over time, as well as the connected set of beliefs, values, knowledge, and skills that influence and are influenced by this reengagement and are distributed across family members.*

This definition has a number of implications for research. First, the family, including parents, children, and other significant adult caregivers, is assumed to be the appropriate unit of analysis for understanding changes in interest development. From this perspective, the family represents a dynamic system, defined by "the communication patterns and processes that link family members" (Jaskiewicz et al., 2017). These communication and interaction patterns help define the "rules that govern" the family system (Johnson & Ray, 2016, p. 783), such as "boundaries, roles, rules, hierarchy, climate, and equilibrium" (Christian, 2006). Specific to interest, we expect the components and phases of interest development, such as those outlined in the four-phase model, to be distributed or emergent across family members.

Second, we expect that families develop patterns and routines related to emerging interests that change and evolve in response to ongoing influences within and outside of the family. An important property of complex systems is the way they both tend toward states of stability and experience periods of dynamic change, influenced by internal and external factors (Cox & Paley, 1997; Davis & Sumara, 2006; Zuiker et al., 2016). These changes are shaped by the ongoing connections, influences, and feedback loops among family members, which in turn shape and are shaped by other systems in which the family is situated (Broderick, 1993; Jaskiewicz et al., 2017; White et al., 2015).

Finally, analysis of the interest system requires close attention across multiple levels: individual system components (e.g., parents and children), connections between components (e.g., parent–child interactions), emergent properties of the system as a whole (e.g., family routines and interest-related re-engagement behaviors), nesting of the system within other systems (e.g., parent–child dyad, other family members, the program and school learning contexts), and changes to the system over time (e.g., evolving patterns of family engagement). In other words, a system perspective requires attending to not only the reciprocal influences within the family but also the ways that the family influences and is influenced by other systems of which it is a part, such as school, society, and broader cultural communities (Bronfenbrenner, 1979; NASEM, 2016).

Research Questions

Based on the prior literature and our theoretical framework, this study was designed to address two broad questions about interest development for preschool-age children and their families participating in the HSE program:

1) What does early childhood engineering-related interest development look like for parents and children participating in HSE, as viewed from a systems perspective?
2) What are the critical components, distinguishing characteristics, and significant shifts of these evolving systems?

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The study was intended to contribute to theory and practice in several ways. There is a broadly acknowledged need to better understand the processes and mechanisms underlying interest development, both in early childhood and beyond (Chesworth, 2016; Crowley et al., 2015; Renninger et al., 2015). This investigation was intended to expand our understanding of interest development and explore the potential of a family systems perspective to shed light on these processes. For educators and policy makers, a deeper understanding of how interests develop in early childhood, the role of families and parents, and how this process can be supported is essential for creating programs that foster long-term interest pathways. For the engineering education field specifically, this work was intended to address a fundamental gap in our understanding of engineering engagement and interest development in early childhood and to inform long-term efforts to broaden participation in the engineering field, especially for low-income English- and Spanish-speaking families.

Methods

To address the research questions above, we conducted qualitative case study research (Yin, 2018) with 15 families participating in the HSE program during the 2016–17 school year.[2] The case study approach allowed us to coordinate a variety of data sources, authentically attend to the perspectives of parents and children, and explore the complexity of the family system.

Program Context

Study participants were part of MHCC Head Start and had been recruited to participate in the HSE program specifically. Head Start is a national program in the United States designed to help low-income families with children zero through five years old foster healthy development and school readiness. The program includes classroom-based, full- and half-day preschool education, as well as a variety of family support services. Families are eligible to participate if their household income is below the federal poverty line, they receive state or federal income-based public assistance, or they are classified as homeless. In 2017, Head Start served over one million children across the United States (Office of Head Start, 2018). At the time of the study, the MHCC Head Start program included approximately 1,300 enrolled families. Of these, 44% identified as Hispanic or Latino and 28% reported their primary language as Spanish—by far the most common language spoken after English.

HSE is a multicomponent, family engineering engagement program integrated within the Head Start model and iteratively developed and improved since 2015 in close collaboration with MHCC Head Start staff and families. The program focuses on fostering family interests in the engineering design process and is intended to prepare low-income families with preschool children (ages three to five) for a world where science and engineering are now ubiquitous (Pattison et al., 2017). The engineering design process is a cycle that engineers follow to create and test solutions to a problem, including asking, imagining, planning, creating, and improving (Cunningham, 2018). HSE emphasizes the engineering design process in particular, rather than the field of engineering, as a topic and skill that is highly relevant to the everyday lives of families, makes engineering feel more approachable, and easily connects to early childhood play and learning practices.

The approach to the engineering design process embodied in the HSE activities builds on prior National Science Foundation-funded work by the second author as part of the Gender Research on Adult-Child Discussions in Informal Engineering Environments (GRADIENT) project. GRADIENT was one of the first studies to explore how very young children and their parents engage in engineering activities within a museum context. Findings highlighted the engineering behaviors of problem scoping and idea generation as both possible and frequent for parent–child dyads (Cardella et al., 2013; Dorie et al., 2014, 2015) and suggested that young children tended to more fully participate in engineering activities when parents were less directive in their interactions (Svarovsky et al., 2017). Videos of families engaging with the HSE activities also suggest that parents and children are able to engage in different elements of the engineering design process, including problem scoping and idea generation, much like the family groups in the GRADIENT study (Dorie et al., 2014; Svarovsky et al., 2017).

HSE Program Components

During the 2016–17 school year, the primary HSE program components were: (a) four bilingual (Spanish/English) family take-home activity kits, each with a storybook, activity materials, and a parent facilitation guide; (b) professional development workshops for Head Start teachers; (c) three parent workshops to introduce the take-home activity kits;

[2] To our knowledge, HSE was the only engineering-related program that these families and this Head Start organization were or had been involved in at the time of the study.

Figure 1. Primary components of the HSE program.

(d) home visits by Head Start staff; (e) classroom activities to complement engagement at home; and (f) a culminating field trip to OMSI (see Figure 1). These are described in more detail below.

The ***take-home activity kits*** serve as anchor experiences for the program, each focusing on an age-appropriate engineering design challenge based on a storybook. The books were selected to provide context and motivation for the engineering design challenges, with the challenges often emerging from the story narratives. Three out of the four books were originally written in English and one of the books was written in Spanish. All books were translated to include both Spanish and English text on each page. The design challenges for the activity kits included: building a tower to protect a hen from a one-foot tall fox (based on Svarovsky et al., 2017); creating a safe path to help a "mouse" (i.e., ping pong ball) escape from a cat and bring food to her family; designing and testing different bubble wands and bubble solutions for children to use in the bath; and designing a comfortable nest to hold a baby bird. The materials in the kits included both accessible and everyday materials, as well as more novel objects. For example, the *Fox and the Hen* activity kit included a set of foam blocks and pictures of a fox and a hen, while the *Mouse Run* activity included paper towel rolls to create a path for the mouse. Each kit also included a bilingual parent facilitation guide with activity instructions, discussion prompts, and ideas for activity extensions.

Parent workshops introduce parents to the family take-home activity kits and connect the engineering design process to their everyday lives, as well as early childhood play and learning practices. All parent workshops were developed and facilitated in Spanish and English by members of the HSE team with the help of Head Start staff. The workshops took place at the Head Start location and started with a community dinner for both adults and children. Following dinner, most children went to a separate room for childcare while parents attended the workshop. During the workshops, program staff shared more about engineering with parents, introduced and let parents explore each take-home activity kit, discussed strategies for engaging their children in the activities, and facilitated conversations among parents about their experiences with the kits at home. The team also introduced parents to a version of the engineering design cycle (ask, imagine, plan, create, improve) (Cunningham, 2018) and continually revisited this cycle to help parents and staff become more familiar and comfortable with the design process. After each workshop, parents took home their own copies of the activity kits introduced during that meeting. Most parents attended the workshops. However, if a parent was unable to attend, they received the activity kit from their Head Start teacher. The workshop series culminated in an end-of-year ***field trip to OMSI***, when all the staff and families from the participating Head Start location were invited for an evening at the museum with dinner and time to explore the science and engineering exhibits.

Finally, the HSE program also includes ***yearly professional development workshops*** for Head Start teachers with the goal of empowering teachers to incorporate engineering and the engineering design cycle into their classrooms. Similar to the parent workshops, the professional development workshops were designed to increase teachers' understanding of

Table 1
Case study participant descriptions.

ID	Primary caregiver name	Primary child name	Preferred language	Case study group	Child age (years)	Other family members at home (child age)
2	Lilliana	Marcos	Spanish	Focal	4	Father, older sister (8)
3	Rosa	Enrique	Spanish	Comparison	4	Father, younger sister (1)
5	Cecilia	Patricia	Spanish	Focal	4	Father, younger brother (3) and sister (1)
6	Molly	Charlie	English	Focal	4	Two adult sons (Charlie's uncles)
8	Marisol	Pepita	Spanish	Focal	4	Father, older sister (19)
10	Aida	Adelina	Spanish	Comparison	4	Father
11	Sarah	Alice	English	Focal	4	Father, older sister (8), younger brother (3)
13	Katie	Devin	English	Focal	4	Father
15	Bethany	Becky	English	Comparison	5	Younger brother (1)

Note. All participant names in this article are pseudonyms. Focal case study participants were involved in all aspects of the HSE program. Comparison case study participants were only involved in the initial engineering night, the classroom activities, and the final OMSI visit.

and comfort with the engineering design process and to make connections with early childhood play and learning. The professional development workshops were created and delivered by the project team, which included an engineering education professional (second author). All teachers that participated received the same family take-home activity kits to adapt for use in the classroom and reported using these kits for the duration of the program. The teachers also built on these experiences during their regular ***home visits*** and parent–teacher conferences, checking in with participating families about the program and offering additional tips and resources.

Study Participants

Of the 40 families that participated in the program during the 2016–17 school year, we recruited 15 to take part in the case study research, eight of which reported primarily speaking Spanish at home. To increase the variation within our sample and highlight potential differences in interest development patterns over time, nine of the families recruited for the study (focal group) participated in all aspects of the HSE program, as described above, and six participated in everything but the parent workshops (comparison group). All 15 families received an annual membership to OMSI as a thank-you gift for participating in the study. Once data collection was complete, we selected nine families for in-depth, case study development, balancing the goals of (a) representing the diversity of program participants and (b) allowing for in-depth analyses of a small number of participants, as appropriate to qualitative research (Creswell, 2013). The characteristics of these final case study families are outlined in Table 1.

Data Collection

Data collection with each of the recruited families took place over approximately six months, during and after their participation in HSE. This included an initial informed consent meeting and background interview, observations and video recordings of all program events, two home visits during which researchers interviewed parents and children and videotaped the families engaging with the take-home activity kits, and a final phone call with parents at the end of the program. Prior to the research starting, researchers participated in home-visit training with Head Start staff to ensure the team followed Head Start protocol and best practices. Each researcher was assigned a group of families for the duration of the project and conducted the initial informed consent meeting and background interview with parents while accompanied by their respective Head Start teachers. The subsequent home visits only included the assigned researcher. Throughout, researchers and families communicated through text messaging and phone calls to schedule data collection activities.

Interviews during the home visits included warm-up activities (e.g., drawing a favorite animal, building with Play-Doh), reflections from both parents and children on previous HSE program events, and reflections on interest development and interest-related activities within the family. For videotaped parent–child interactions, researchers asked families to play with one of the HSE take-home activity kits as they normally would, set up the video camera, and then left the house until the family was finished. The researchers also collected secondary data through images and objects shared by families, teacher journals, and evaluation feedback from staff and participants. Finally, researchers completed reflective memos after every data collection event and throughout the data analysis process described below.

Data Analysis

Following a multiple case study approach (Yin, 2018), the team developed case study reports for the nine families that detailed: (a) the families' experiences throughout the program; (b) evidence of interest development at multiple time points; and (c) family, program, and contextual factors that potentially shaped family interests. Although we focused on interest development related to the engineering design process, we remained open to the variety of ways families interpreted and engaged with this process in order to capture the unique and varied interest pathways of participants (Azevedo, 2011, 2015).

During analysis, two members of the research team reviewed and coded the videotaped parent–child interactions, including how families used the engineering design process. The video coding built on the analytic framework developed through the GRADIENT project (Svarovsky et al., 2018) and focused on evidence of families: problem scoping, generating ideas, evaluating and revising their designs, and using the words "engineer" or "engineering." Written summaries of these interactions and coding results were then added to each case study, providing a micro-level analysis of parent–child interactions to complement the broader description of family experiences. Draft case studies were iteratively reviewed by the research team to identify emergent themes within and across families, with a particular focus on understanding and operationalizing the family-level interest development system.

Both data collection and analysis were conducted in Spanish and English, in ongoing collaboration with MHCC Head Start staff members to ensure that the team was sensitive to the unique experiences, values, and cultural beliefs of this community. The research team included two members (third and fourth authors) who are fluent in Spanish and English and self-identify as bicultural (Hispanic/American). One of these researchers is from Puerto Rico and the other is from Cuba, and both have years of experience working with Spanish-speaking families in the region in which the study took place. The first author, who led the research team, also has advanced proficiency in Spanish. The two bilingual researchers collected and analyzed all data from the Spanish-speaking case study families, maintaining the data in the original language throughout the process, and then collaboratively developed case study descriptions for these families in English that could be reviewed by the entire research team. Throughout the process, the team was sensitive to not only differences across Spanish- and English-speaking families but also the cultural diversity within both of these groups (e.g., Capielo Rosario, Adames, Chavez-Dueñas, & Renteria, 2019; Stepler & Brown, 2016).

Results

This study focused on investigating two research questions: (1) What does early childhood engineering-related interest development look like for parents and children participating in HSE, as viewed from a systems perspective? (2) What are the critical components, distinguishing characteristics, and significant shifts of these evolving systems? In our analysis, we focused on identifying emergent evidence of engineering-related interest development across multiple aspects of the family system. The qualitative, cross-case analysis highlighted three aspects of family-level interest development that varied across families and over time: (1) parent awareness, knowledge, and values; (2) family re-engagement with engineering activities; and (3) family use of the engineering design process. Within each of these categories, we identified important shifts that were observed in a subset of the families and that potentially signal movement to deeper, sustained levels of engineering interest (Table 2).

Table 2
Summary of qualitative themes.

Theme	Description	Critical shift
Parent awareness, knowledge, and values	Parents demonstrated evidence of broadening and deepening their understanding of the engineering design process, increasing their confidence with the topic of engineering, and developing an appreciation of the relevance of engineering to daily life and their children's learning and development.	*Seeing engineering everywhere*—Evidence that seeing engineering everywhere allowed families to incorporate engineering beyond a specific program and connect the topic with other family interests.
Family re-engagement with engineering activities	Beyond their initial engagement with the program, families reported re-engaging with HSE program materials and activities multiple times over the course of six months.	*Going beyond the HSE activities*—Evidence that family interests had begun to generalize beyond the specific program materials and activities toward broader topics or activity preferences, such as building and designing structures or using the engineering design process.
Family use of the engineering design process	Observation and interview evidence of parents and children incorporating engineering design into their interactions and parents changing their perspectives on engaging and interacting with children related to engineering.	*Taking on new roles*—Evidence of parents or children taking on teaching roles with engineering-related activities, such as in the classroom or with friends.

Theme 1: Parent Awareness, Knowledge, and Values

Aligned with a family systems perspective, the data highlighted the multiple ways that parents changed as the families deepened their engagement with and interest in the HSE program and other engineering-related activities and experiences. Through the parent interviews and the videotaped parent–child interactions, we observed all but one of the families broadening and deepening their understanding of the engineering design process, increasing their confidence with the topic of engineering, and developing an appreciation of the relevance of engineering to daily life and their children's learning and development. Parents mentioned changes related to expanding their awareness of what engineering is, being more comfortable talking to their children about engineering and facilitating engineering-related activities, identifying ways that they used the engineering design process with their children during the HSE activities, and increasing their value for engineering in early childhood. During our observations of parents and children interacting together with the HSE activities, we also noted increasing parent comfort facilitating the activities and incorporating aspects of the engineering design process, such as planning and improvement.

For example, reflecting back on her experience with the entire program, Lilliana (family 2) noted that engineering seemed more accessible and that she felt more comfortable talking to the children about it. She mentioned that engineering is something they can do and practice: *"Se divierte y aprende más cosas—sobre todo lo que es la ingeniería. No es solamente hacer cosas muy grandes, si no se pueden hacer cosas pequeñitas y uno está practicando la ingeniería." (You can have fun and learn more things—especially what engineering is. It's not only doing large things, but you can also do little things and you will be practicing engineering.)*[3] Marisol (family 8) contrasted her new understanding of the relevance of engineering to the surprise of her relatives in Mexico when they heard about the program: *"Se lo conté a mi familia en México, y me dijeron que extraño que había un programa para ingeniería para una niña tan joven. Y yo les expliqué lo que era el programa." (I told my family in Mexico, and they told me it was strange to have an engineering program for a girl so young. I explained what the program was to them).*

Although this theme was nearly universal for all of the case study families, there was considerable variation across parents in terms of how their beliefs and values changed. Some family members, such as Lilliana, reflected on their growing awareness of engineering as an important skill for their children to learn and practice. Other families discussed engineering, or the HSE activities and materials, more as a tool for supporting their children's learning and development in general. For example, Molly (family 6) described her value for the program in terms of providing an opportunity for her grandson, Charlie, to become socialized and engage in structured playtime. Similarly, Cecilia (family 5) said that the activities helped her read more to the children and get them excited about new ideas.

Theme 1 Critical Shift: Seeing Engineering Everywhere

Several parents reported how their broadened perspectives on engineering helped them see engineering and the engineering design process in daily life. Coupled with the growing value for engineering, especially as it related to their children's learning and development, this may represent an important shift by allowing families to incorporate engineering beyond a specific program and connect the topic with other family interests. From a systems theory perspective, parent awareness about engineering everywhere may disrupt family patterns and routines by expanding the number and type of opportunities that parents and children have to talk about and engage with engineering throughout their lives.

Four out of nine of the case study families showed at least some evidence of this critical shift. For some families, this involved understanding and highlighting how all the objects and structures in their lives had been engineered by someone. Sarah (family 11) talked about how she and her husband tried to help their children see engineering all around them and notice that *"things had to be engineered, planned, and thought of."* Other families discussed the engineering design process as something that is relevant to everything that parents and children do in their lives. For example, Molly (family 6) mentioned that her family *"used engineering thinking when they loaded our moving truck, didn't we Charlie? We had to figure out how to put in all those boxes."* Similarly, Katie (family 13) noted that prior to the program, she thought *"about engineering as something big and you don't really know much about, but it's everywhere, and you don't really understand it fully until you experience it and realize it's literally in everything you can do."* When asked about some of the potential benefits of the program, Lilliana said: *"Cuando se habla de ingeniería podemos imaginarnos que es algo que nosotros mismos podemos hacer. Es algo que en un sentido se puede estudiar como para hacer edificios y puentes, algo asi, pero la ingeniería está a nuestras manos y el programa nos ha demonstrado eso." (When we are talking about engineering, we can*

[3] All interviews and study data were analyzed in the original language of the participants. The English translations for the Spanish quotes included in this article were done by the third author and then reviewed by at least one other bilingual member of the research team.

imagine that it's something that we can do ourselves. It's something that in one sense we can study, like if we were to make buildings, bridges, or something like, but engineering is within our reach. And the program has shown us that.)

Theme 2: Family Re-engagement with Engineering Activities

An important indicator of interest development is re-engagement with the interest topic, activity, or object (Hidi & Renninger, 2006; Renninger & Hidi, 2011). Beyond their initial engagement with the program, all of the case study families but one reported re-engaging with HSE program materials and activities multiple times over the course of six months. After receiving their take-home engineering activity kits from the parent workshops, families continued to read the books and use the activities at home, involved more family members and friends in the activities beyond the original parent–child dyad, found additional materials to use with the activities, and developed new challenges and variations. Some families incorporated these activities into regular family routines, and some reported seeking out new engineering-related resources and learning experiences beyond HSE. This re-engagement was motivated by parents, children, or both, depending on the family.

For example, Sarah (family 11) shared during the third home visit that her daughter Allison *"is still getting out the blocks and building whatever she can…[and] always reminding me how she's protecting the chickens."* Sarah attributed this interest in the activity to the fact that the children had not owned blocks before and that the kits *"gave [the kids] something always to do. They can always pull the blocks out and play with them."* Lilliana's family also continued investigating the fox and hen activity: "*Bueno primero lo hicimos y no era tan protector para la gallina y lo hemos practicado. Marcos lo ha practicado más. Él lo imagina y nosotros le decimos así se puede caer y se ha ido mejorando." (The first time we did it, it wasn't as protective for the hen, so we have practiced. Marcos has practiced the most. He imagines it and we tell him that it could fall and so he makes it better.)* Katie (family 13) discussed continuously re-engaging with and altering the mouse activity with her son, using different types and numbers of tubes and balls and bringing in other materials, such as connector pieces from her son's train set. She noted, it *"was cool to find different ways and different outcomes."*

For some families, such as Cecilia and Patricia (family 5), reading the HSE books and doing HSE activities became part of their daily family routine. In fact, several parents commented how an important outcome of the project was providing their families with more resources and ideas to help them play and spend time together as a family. Some teachers even commented on how familiar children had become with the activities when they were introduced in the classroom, as was the case with Pepita (family 8).

Theme 2 Critical Shift: Going Beyond the HSE Activities

Beyond using the materials provided through the program, several families began to seek out or develop new engineering-related activities. In other words, the interests for these families had begun to generalize beyond the specific program materials and activities toward broader topics or activity preferences, such as building and designing structures or using the engineering design process. From a theoretical perspective, this may represent an important shift, indicating a developing interest in the broader topic of engineering design. This distinction is aligned with how Hidi and Renninger described the transition from maintained situational interest to emerging individual interest, which they defined 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*" (Hidi & Renninger, 2006, p. 114, emphasis added).

For example, during the final phone call, Bethany (family 14) noted that her daughter, Becky, had extended her interest in the HSE activities when she had the opportunity to help her grandparents in their garden, which included building a structure for their grapes to grow on. Bethany also noticed that Becky had begun *"asking how everyday things operate, which she wasn't doing before we started [the HSE program]. Now she's into trying to figure out how everything works and why things are built certain ways."*

Seven of the nine case study families showed evidence of this critical shift. In discussing these changes, some parents focused on the use of books, while others focused on new or repurposed materials. Katie (family 13) and Molly (family 6) were particularly inspired by the idea of using children's books to come up with new hands-on activities and engineering design challenges. Katie shared that she is now frequently trying to use different books to come up with other projects to do with Devin based on the materials they have at home. Even when they lack materials, she said that they will just talk about the book and imagine a project that they could do together. Similarly, the concept of using a storybook to engage in a hands-on activity seemed to resonate with Molly. She reported going to the library to find books that she could use to invent activities for her and her grandson. Beyond the books, Marisol's daughter, Pepita (family 8), was inspired to use new materials to build a corral and spaceship for her pet guinea pig. And Lilliana reported that her husband had been looking for ways to repurpose or use the kit materials for other family activities: *"El programa nos ha inspirado, no tanto a comprar pero a crear." (The program has inspired us not so much to buy but to create.)*

Theme 3: Family Use of the Engineering Design Process

Analysis of the videotaped in-home parent–child interactions with the HSE activities highlighted ways parents and children incorporated this process into their interactions (e.g., planning and improvement). Interviews also highlighted changing parent perspectives on engaging and interacting with children, such as appreciating that there is "no wrong way" to solve an engineering design challenge. From a systems perspective, this indicates that not only were the individual elements of the system changing (i.e., parents and children), but also the relationships between these elements (i.e., the ways that parents and children interact with each other). Six of the case study families showed evidence of this theme.

Across the videotaped parent–child interactions, we saw numerous examples of the engineering design process, including asking, imagining, planning, creating, and improving. Families found ways to: improve and revise their designs; ask questions about the engineering problem, goals, and materials; discuss different design options; encourage each other to continue trying when things did not work; imagine different options; and talk about next steps. During the mouse activity, Katie (family 13) noted that she was *"always thinking about the next step and how it [would work] in the scheme of [the activity]."* This was visibly demonstrated in the ways she and her son adapted the activity, introducing different kinds of balls, materials, and toys. With the same activity, Marisol and her daughter (family 8) evidenced questioning and planning by discussing their approach to building a path for the mouse and the cat (*"Si no lo pones derecho el ratón no puede pasar rápido" [if you don't put it straight the mouse cannot pass quickly]*). Marisol also appeared to model behaviors she wanted to support in her child, such as encouraging iteration and improvement. In her interview, Bethany (family 14) reflected that the engineering design process is not always clean and linear. She noted that she and her daughter often paid less attention to the planning step and instead just started to create, which would often *"lead to more questions and talking more together."* For example, when rearranging Becky's room, Bethany reported that they used *"a similar process"* to engineering design but that they had *"eliminated the planning part because we just jump right in there."*

In the conversations with parents and children, some families were more reflective of their use of the engineering design process than others. Lilliana (family 2), for example, talked at length about her family's use of engineering design. She reported that she had realized there is "no wrong way" to do things and that she had taken a more open approach to facilitating the activities for the children, allowing them to explore and imagine and reminding them they can always improve: *"No hay ninguna forma mala de hacer las cosas, así que no tengo que ser tan estricta de decirle no así no está bien…[El programa] me ha ayudado a entender que el puede hacer las cosas a su manera y puede usar su imaginación…No hay nada incorrecto, todo esta bien porque estamos aprendiendo y…lo podemos mejorar, todo lo podemos mejorar." (There is no wrong way to do things, so I don't have to be so strict by saying no, not that way, that way is wrong. The program has helped me understand that he can do things his own way, and he can use his imagination. There is nothing wrong, everything is fine because we are learning and we can improve, we can improve everything.)* In contrast, Cecilia (family 5) did not seem comfortable talking about the engineering design process during the home visits, although in the analysis of her and her daughter on video, we observed the family consistently using questioning, imagining, planning, and improving.

Theme 3 Critical Shift: Taking on New Roles

Although most families demonstrated ways that they were incorporating the engineering design process into their interactions and daily routines, a few families also reported that either the parent or child had begun taking on teaching roles with engineering-related activities, such as in the classroom or with friends. In other words, they facilitated the engineering design process for others, rather than only using it themselves within the family system. This role change may represent an important shift in terms of new skills and identities related to the interest development process. A teaching role provides opportunities for an adult or child to increase their own awareness about their developing interests and expertise related to engineering and be recognized by others as someone who is into and knowledgeable about this topic (Carlone & Johnson, 2007). It also represents a compelling shift in motivation, from not just enjoying engineering for oneself but to being interested in sharing the topic and activities with others.

Three of the case study families showed evidence of this critical shift. Rosa and Enrique (family 3) and Mollie and Charlie (family 6) all discussed ways they had begun facilitating the HSE activities for other friends and family members. Molly said that Charlie *"would always bring the Fox and Hen activity when his friends came to play, and he gets a sparkle in his eyes when he gets to show them how to play with it."* Similarly, Rosa reported that she and her son, Enrique, had started facilitating the mouse activity for Enrique's cousins, including changing the design so that more children could participate. During the interactions, Rosa reported that Enrique played an important role by showing his cousins how to use the activity.

Katie (family 13) took on a teaching role in a different context, as a volunteer in Devin's Head Start classroom. She described how during one recent free-choice playtime period, she pulled out the fox and hen activity for the students, despite, as Katie noted, some initial hesitation from the teacher. By the end of playtime, many students had congregated around the activity, which prompted Katie to distribute blocks to all of the children and let them build their own structures. During this process, Devin also became very excited because he was able to assume the role of teacher and show his friends how the activity was done. Similarly, Katie and the Head Start teacher led the bubble wand activity with the students during their outdoor playtime. They not only built wands but also ran experiments to see which bubble mix, store-bought or the program recipe, worked better.

Discussion

In this study, we sought to use a systems perspective to understand how preschool-age children and their families developed engineering-related interests through their participation in the HSE program. Through the qualitative analysis of nine case study families over approximately six months, we documented how parents, children, and parent–child interactions evolved as families shaped their own unique interest pathways. Three themes emerged from the analysis, representing evidence of engineering-related interest development within the family system: (1) changes in parent awareness, knowledge, and values; (2) evidence of family re-engagement with engineering activities; and (3) increased family use of the engineering design process. Within each of these themes, we observed evidence of critical shifts that may represent how some of these families moved toward deeper, more sustained levels of engineering-related development, such as parents seeing engineering everywhere or families engaging with engineering-related activities beyond those provided through HSE.

The case studies highlighted the potential of adopting a family-level systems perspective for understanding interest development in early childhood, including the role of parents. Systems theory requires broadening the unit of analysis beyond the individual, capturing emergent and distributed system properties, and attending to patterns of both stability and change. Across research participants, we observed interest-related changes in beliefs and behaviors well beyond the individual child, including changes in parental beliefs and behaviors, new roles for both children and parents, and shifts in family routines and practices. Throughout, the data suggested that parents in this study were not just a contextual factor but instead were part of the interest development system, both influencing and being influenced by their children. Some of the changes we observed appeared to reside primarily in the individual elements of the system, such as evolving parental beliefs and values related to engineering. Other changes, however, highlighted shifts in the system as a whole, including changing family routines related to the use of the HSE activities. At certain points during the program, we observed system-level shifts, such as interest in activities beyond HSE that expanded family engagement in the engineering design process.

Other researchers have suggested the value of using systems theory to study family learning and interest development (Cox & Paley, 1997; Hedges & Cooper, 2016), but there have been few attempts to operationalize this perspective. In the current study, we have provided an example of one approach to investigating family-level system changes in interest development using a multiple case study approach. One ongoing challenge will be to develop tools and strategies for researching these patterns and processes at a broader scale. Case study methods provide an excellent way to capture the complexity of family systems and integrate data from multiple sources (Creswell, 2013). However, the approach is less appropriate for testing hypotheses, generalizing findings to larger populations, or making strong causal claims. On the other hand, traditional quantitative strategies like surveys and randomized control trials often assume linear causal relationships that are at odds with a systems perspective (Cox & Paley, 1997).

There are also many opportunities to expand the systems lens and capture a broader perspective on the interest development system, both within and outside of families. Cox and Paley (1997) recommended that early childhood researchers move beyond the parent–child dyad and think about the family as a series of nested systems, including other family members and the broader cultural and institutional landscape in which families exist. Although our case studies attempted to capture influencing factors and processes, data collection and analysis focused primarily on the caregiver and child participating in the HSE program. Even widening the systems lens to include siblings and other adult family members would likely provide a richer perspective on interest development. For example, in families with multiple children, we observed that older siblings often became interested in the activities as well and seemed to influence how the families engaged with the engineering design process.

Another open question for research is how the engineering-related interests that we documented relate to the broader set of preferences that children and their families are developing at this age. Focusing on indicators of interest related to the engineering design process was helpful for bounding this study. However, we agree with Azevedo (2011, 2015) that people do not neatly subdivide their interests based on content domains or academic disciplines. Interestingly, although families discussed engineering extensively in the interviews, not a single family used the words "engineer" or "engineering" during the videotaped parent–child interactions. Future research can explore the extent to which families associate their developing interests with specific topics or academic domains, how these interests relate to other preferences and engagement patterns, and what the long-term implications of these different interest pathways are for children.

Implications for Practice

Existing early childhood science and engineering programs often focus on the formal classroom context (Cunningham, 2018; McClure et al., 2017; NASEM, 2020). While we do not deny the value of these programs, as this and other studies suggest, the family and the home are rich and often under-appreciated settings for learning and interest development (Dou, Hazari, Dabney, Sonnert, & Sadler, 2019; Strickler-Eppard, Czerniak, & Kaderavek, 2019; Vedder-Weiss, 2017). Long after children and parents leave a program, it is what continues to go on at home that will influence the persistence of program outcomes (NRC, 2009). By taking parents seriously as learners and partners in the interest development process, early childhood educators can complement and extend what is going on in the preschool classroom (NASEM, 2016; Takeuchi, Vaala, & Ahn, 2019). This requires taking a systems perspective not just on research but also program development and implementation—engaging multiple aspects of the family system across different contexts (e.g., the classroom, the home, parent workshops) and strategically planning for the overlap and synergy across these experiences (Bevan, Garibay, & Menezes, 2018; NRC, 2015).

Applying a systems lens to early childhood education also requires a shift in how we conceptualize learning goals. For example, what goals do educators have for parents and caregivers, and how do these relate to goals for children's learning? This study suggests that helping parents understand how a topic such as engineering relates to their everyday lives and supports learning and development for their children can provide a catalyst for ongoing, self-motivated family engagement, at least in the context of the HSE program. And just as many early childhood programs have goals for literacy practices in the home (e.g., Canfield et al., 2018; Neuman & Kaefer, 2018; Popov, Tinkler, Tore, & Meschen, 2017), what vision do we have for how families develop learning routines around topics like engineering and incorporate these into everyday interactions? In thinking about these goals, educators must be mindful of the multiple cultural perspectives and approaches to parenting (Lareau, 2003; Rogoff, 2003; Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo, 2003). Our study documented the variety of ways that these families participating in the HSE program engaged with engineering, sometimes led by children, sometimes by parents, and sometimes both. Rather than being restrictive, we argue that educators and researchers should honor the diverse ways that families develop and extend their interests in engineering and other topics.

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