ENGINEERING IN EARLY CHILDHOOD: DESCRIBING FAMILY-LEVEL INTEREST DEVELOPMENT SYSTEMS

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Engineering is an important STEM career and a critical life skill, helping individuals to solve problems and create solutions in school, work, and life. Unfortunately, the engineering field suffers from a lack of diversity (Brophy et al., 2008; Hill et al., 2010; NSB, 2016) and many individuals from traditionally underserved and under-resourced communities do not have access to high-quality engineering learning experiences. Diversifying the engineering workforce and ensuring that individuals from all backgrounds have the engineering skills to succeed in work and life requires (a) providing quality engineering learning opportunities for all from the earliest age and (b) building children's and families' interests in engineering to motivate ongoing engagement and learning. STEM-related interests form well before children enter school and have implications for long-term engagement (Alexander et al., 2012; Crowley et al., 2015; Maltese & Tai, 2010). We still understand very little, however, about how these early interests develop and how they can be supported (Alexander et al., 2015; Pattison & Dierking, 2017).

In this paper, we summarize the results of the two-year, National Science Foundation-funded *Head Start on Engineering (HSE)* project,[1] designed to study and support engineering-related interest development for preschool children and their families from low-income backgrounds participating in Head Start.[2] Low-income communities face ongoing barriers to accessing STEM learning resources and pursuing STEM-related careers (Bassok et al., 2016; Crisp & Nora, 2012; Gershenson, 2013; NSF, 2016; ED, 2014). Quality family interventions in early childhood are a critical approach to addressing these barriers (McClure et al., 2017; NASEM, 2016; NRC, 2009) and have been shown to have long-term, positive impacts on families well beyond success in school (Garcia et al., 2016; Gertler et al., 2014; Grantham-McGregor & Smith, 2016; Heckman, 2012).

Theoretical Framework

In order to understand how engineering-related interests develop in early childhood for low-income families, this study applied a systems perspective to family learning. Interest is a complex, motivational construct that drives human behavior (Renninger & Hidi, 2011; Silvia, 2006), including choices about engaging with STEM topics, activities, and careers (Azevedo, 2015; Renninger, 2007; Renninger et al., 2015). According to the four-phase model of interest development (Hidi & Renninger, 2006), interest begins as a spark of emotion in a specific moment that compels us to engage, explore, and find out more about a particular topic, object, or activity. If sustained, this initial "situational interest" can develop into a more enduring predisposition to engage and learn. Through this process, the positive emotion 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 (Renninger & Su, 2012).

To date, interest has primarily been described as an individual-level construct. *In early childhood, however, learning and development are arguably best conceptualized as multi-directional and distributed* (NRC, 2000; Pattison et al., 2016; Sameroff, 2009). In other words, (a) parents and other significant adults change and learn in parallel with children and (b) learning and development are facilitated or supported by adults as children gradually develop more skills, knowledge, autonomy, and self-regulation (Hume et al., 2015; Martin et al., 2013; NASEM, 2016; Pattison, 2014; Rogoff et al., 1993; Vygotsky, 1978). More than static inputs or contextual variables, parents must be seen as learning partners in ongoing STEM interest pathways (Crowley et al., 2015; Pattison, 2014; Pattison & Dierking, 2017). Parent-initiated experiences support children's interests (Ainley & Ainley, 2015; Barron et al., 2009), which subsequently influence the nature and outcomes of parent-child experiences (Malin et al., 2014), such as when a child develops an area of expertise and parents respond by providing new resources, offering encouragement, and learning about the topic themselves (Crowley et al., 2015; Crowley & Jacobs, 2002). Unfortunately, early childhood researchers have been slow to embrace this perspective or develop the methodological tools to understand the family as a system (Cabrera et al., 2014). Drawing from ecological and system theories (Bronfenbrenner, 1979; Davis & Sumara, 2006; Hutchins, 2006; Pattison et al., 2016; Zuiker et al., 2016), therefore, has the potential to shed new light on the process of interest development in early childhood.

Research Questions

Viewing the family as a learning system suggests a different way of thinking about interest development and the changes that might occur as adult and child family members become exposed to a new topic like engineering. Rather than focus solely on the child, we might expect changes in both children and parents,[3] with some aspects

of interest distributed across both children and adults (e.g., positive affect, motivation to re-engage) and some unique to either the adult or child (e.g., age-appropriate skills and knowledge, adult awareness of and value for the topic). These changes in children and parents are likely interrelated in complex ways, with the directionality and timing of the relationships not always clear or measurable (Martin et al., 2013). Furthermore, we might expect phases of interest development, as described in the four-phase model, to be characterized by shifts in both parents and children. Guided by this perspective, we sought to address the following research questions:

1) What does early childhood engineering-related interest development look like for parents and children participating in the *HSE* program, as viewed from a systems perspective?
2) What are the critical components and distinguishing characteristics of this evolving system?
3) How do family interest systems change during and after their participation in *HSE*?

Because emerging studies with young children highlight the important shift from situational interest to more enduring individual interests (Alexander et al., 2015; Pattison, 2014), our study focused on indicators of enduring family-level interests that emerged during the program. Aligned with *HSE*, we focused on interest related to the engineering design process, rather than the field of engineering. This process represents a topic and skill that is highly relevant to the everyday lives of families, helps make engineering feel approachable, and easily connects to early childhood play and learning practices. Building on prior research and the Engineering is Elementary program (Dorie et al., 2014; Lachapelle & Cunningham, 2014; Svarovsky et al., In press), *HSE* introduces families to story-based engineering design challenges and highlights the cyclical process of engineering design (ask, imagine, plan, create, improve).

Methods

The study was conducted as part of the *HSE* project, based in Portland, OR, and lead collaboratively by the Institute for Learning Innovation, Mt. Hood Community College Head Start, Oregon Museum of Science and Industry, and University of Notre Dame (Pattison et al., 2017). *HSE* is a multi-component program integrated into the wrap-around services of Head Start and designed to prepare low-income families with young children (ages 3 to 5) for a world where science and engineering are ubiquitous. The program provides comprehensive services for parents, children, and Head Start staff, including professional development for preschool educators, four take-home engineering activity kits for families, three parent workshops, preschool classroom curricula, and rigorous assessment and program improvement (see Figure 1). The program is aligned with best practices in parent- and family-based early childhood interventions, including viewing parents as equal partners, tailoring interventions to family needs, and integrating services (NASEM, 2016).

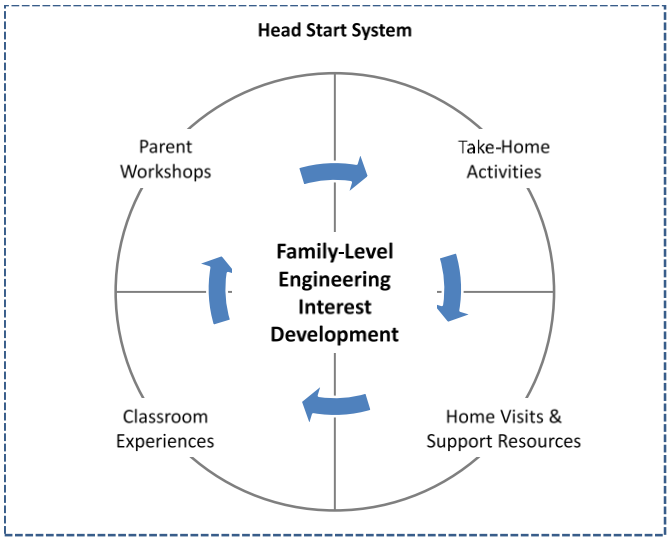

Figure 1. *Head Start on Engineering* program components and theory of action.

During the 2016–17 school year, the research team recruited 15 families (over half of whom spoke Spanish at home) and followed their interest develop pathways over the course of approximately six months. Three researchers (two of whom were bilingual, Spanish/English) were each assigned five families to follow closely. Data collection with each family included an initial informed consent meeting and background interview, researcher 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. The researchers also collected secondary data through images and objects shared by families, teacher journals about the children's experiences in the classroom with the *HSE* activities, and evaluation feedback from staff and participants.

Following a multiple case study approach (Stake, 2006; Yin, 2018), the team developed in-depth case study reports for nine of the participating families (selected to represent the diversity of participants and program experiences) that detailed: (a) the families' experiences throughout the programs, (b) evidence of interest development after each parent workshop and at the end of the program, (c) evidence of changing characteristics of parent-child interactions through analysis of the video data from the home visits, and (d) family, program, and context factors that potentially shaped the unique interest pathways of each family. These case studies were then iteratively reviewed to identify emergent themes within and across families, with a particular focus on understanding and operationalizing the family-level interest development system.

Findings

All families that participated in the *HSE* program showed some evidence of engineering-related interests catalyzed by the program activities. 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. These categories and critical shifts are outlined in Table 1 below.

Table 1. Overview of case study themes related to the evolving family interest development system.

Change in Family System	Description	Evidence of Critical Shift
(1) Parent awareness, knowledge, and values	Through the parent interviews and the videotaped parent-child interactions, we observed parents 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*—Several parents reported how their broadened perspectives on engineering helped them see engineering and the engineering design process in daily life. This may represent an important shift since it allows families to incorporate engineering beyond a specific program and connect the topic with other family interests.
(2) Family re-engagement with engineering activities	Beyond situational interest, all families reported re-engaging with *HSE* program materials and activities. 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.	*Going beyond HSE activities*—Several families began to seek out or develop new engineering-related activities beyond those provided in the program. This may represent an important shift since it indicates a developing interest in the broader topic engineering design thinking.
(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.	*Taking on new roles*—Several families also reported taking on teaching roles during interactions with the *HSE* activities, such as in the classroom or with friends. In other words, they facilitated the engineering design process for others, rather than simply using it themselves. This role change may represent an important shift in terms of new skills and identities related to the interest development process.

Conclusion

The goal of this study was to document and explore how families with preschool children from low-income backgrounds become interested in the engineering design process through their participation in the *HSE* program. A systems perspective was useful for capturing the ways that interest development was distributed across parents and children and for identifying critical shifts that potentially signal movement to more enduring phases of engineering-related interest development.

Reflecting on the utility of this theoretical perspective, conceptualizing the family as an interest system avoided essentializing parents as "contextual factors" and instead highlighted ongoing, interrelated changes in parents, children, and parent-child interactions. Extending the four-phase model (Hidi & Renninger, 2006), some elements of interest development, such as motivation to re-engage with the topic of interest or broadening the focus beyond the program activities, were observed across the whole family. Other elements were unique to adults, including awareness and knowledge of the engineering design process. These unique adult elements may be critical for extending interests at this early age and creating intentional connections between interest-related experiences (Pattison, 2014).

On the other hand, operationalizing this perspective presented many challenges. Traditional data collection techniques, such as parent surveys, provide only one perspective on the family system and other strategies, such as videotaping and home visits, are more expensive and difficult to implement on a large scale. Moving forward, we hope to develop a suite of tools for quantifying the elements of family interest development identified in this study, tracking these elements over multiple years as children enter kindergarten, and measuring the long-term impact of *HSE*. Ultimately, we believe a family systems perspective on interest development can not only advance our theoretical understanding of interest, but also help us to develop more holistic and effective programs for engaging families with young children in STEM.

References

Ainley, M., & Ainley, J. (2015). Early science learning experiences: Triggered and maintained interest. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in mathematics and science learning* (pp. 17–32). Washington, DC: American Educational Research Association.

Alexander, J. M., Johnson, K. E., & Kelley, K. (2012). Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education, 96*(5), 763–786.

Alexander, J. M., Johnson, K. E., & Leibham, M. E. (2015). Emerging individual interests related to science in young children. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in mathematics and science learning* (pp. 261–280). Washington, DC: American Educational Research Association.

Azevedo, F. S. (2015). Sustaining interest-based participation in science. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in mathematics and science learning* (pp. 281–296). Washington, DC: American Educational Research Association.

Barron, B., Martin, C. K., Takeuchi, L., & Fithian, R. (2009). Parents as learning partners in the development of technological fluency. *International Journal of Learning and Media, 1*(2), 55–77.

Bassok, D., Finch, J. E., Lee, R., Reardon, S. F., & Waldfogel, J. (2016). Socioeconomic gaps in early childhood experiences: 1998 to 2010. *AERA Open, 2*(3).

Bronfenbrenner, U. (1979). *Ecology of human development*. Cambridge, MA: Harvard University Press.

Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education, 97*(3), 369–387.

Cabrera, N. J., Fitzgerald, H. E., Bradley, R. H., & Roggman, L. (2014). The ecology of father-child relationships: An expanded model. *Journal of Family Theory and Review, 6*(4), 336–354.

Crisp, G., & Nora, A. (2012). *Overview of Hispanics in science, mathematics, engineering and technology (STEM): K-16 representation, preparation and participation*. Retrieved from http://www.hacu.net/images/hacu/OPAI/H3ERC/2012_papers/Crisp%20nora%20-%20hispanics%20in%20stem%20-%20updated%202012.pdf

Crowley, K. D., Barron, B., Knutson, K., & Martin, C. K. (2015). Interest and the development of pathways to science. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in mathematics and science learning* (pp. 297–314). Washington, DC: American Educational Research Association.

Crowley, K. D., & Jacobs, M. (2002). Building islands of expertise in everyday family activity. In G. Leinhardt, K. D. Crowley, & K. Knutson (Eds.), *Learning conversations in museums* (pp. 333–356). Mahwah, NJ: Erlbaum.

Davis, B., & Sumara, D. J. (2006). *Complexity and education: Inquiries into learning, teaching, and research*. Mahwah, NJ: Erlbaum.

Dorie, B. L., Cardella, M. E., & Svarovsky, G. N. (2014, June). *Capturing the design thinking of young children interacting with a parent*. Presented at the 121st ASEE Annual Conference & Exposition, Indianapolis, IN. Retrieved from http://www.asee.org/file_server/papers/attachment/file/0004/4018/ASEE_2014_Children_Design_FINAL_v3.pdf

Garcia, J. L., Heckman, J. J., Leaf, D. E., & Prados, M. J. (2016). *The life-cycle benefits of an influential early childhood program*. Chicago, IL: University of Chicago. Retrieved from http://heckmanequation.org/content/resource/lifecycle-benefits-influential-early-childhood-program

Gershenson, S. (2013). Do summer time-use gaps vary by socioeconomic status? *American Educational Research Journal, 50*(6), 1219–1248.

Gertler, P., Heckman, J., Pinto, R., Zanolini, A., Vermeersch, C., Walker, S., … Grantham-McGregor, S. (2014). Labor market returns to an early childhood stimulation intervention in Jamaica. *Science, 344*(6187), 998–1001.

Grantham-McGregor, S., & Smith, J. A. (2016). Extending the Jamaican early childhood development intervention. *Journal of Applied Research on Children: Informing Policy for Children at Risk, 7*(2).

Heckman, J. J. (2012). Invest in early childhood development: Reduce deficits, strengthen the economy. *The Heckman Equation, 7*. Retrieved from https://heckmanequation.org/resource/invest-in-early-childhood-development-reduce-deficits-strengthen-the-economy/

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–127.

Hill, C., Corbett, C., St. Rose, A., & American Association of University Women. (2010). *Why so few? Women in science, technology, engineering, and mathematics*. Washington, DC: AAUW.

Hume, L. E., Lonigan, C. J., & McQueen, J. D. (2015). Children's literacy interest and its relation to parents' literacy-promoting practices. *Journal of Research in Reading, 38*(2), 172–193.

Hutchins, E. (2006). The distributed cognition perspective on human interaction. In N. J. Enfield & S. C. Levinson (Eds.), *Roots of human sociality: culture, cognition and interaction* (pp. 375–398). New York, NY: Berg.

Lachapelle, C. P., & Cunningham, C. (2014). Engineering in elementary schools. In Ş. Purzer, J. Strobel, & M. E. Cardella (Eds.), *Engineering in pre-college settings: Synthesizing research, policy, and practices* (pp. 61–88). West Lafayette, IN: Purdue University Press.

Malin, J. L., Cabrera, N. J., & Rowe, M. L. (2014). Low-income minority mothers' and fathers' reading and children's interest: Longitudinal contributions to children's receptive vocabulary skills. *Early Childhood Research Quarterly, 29*(4), 425–432.

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the Fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669–685.

Martin, A., Ryan, R. M., & Brooks-Gunn, J. (2013). Longitudinal associations among interest, persistence, supportive parenting, and achievement in early childhood. *Early Childhood Research Quarterly, 28*(4), 658–667.

McClure, E. R., Guernsey, L., Clements, D. H., Bales, S. N., Nichols, J., Kendall-Taylor, N., & Levine, M. H. (2017). *STEM starts early: Grounding science, technology, engineering, and math education in early childhood*. New York, NY: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from http://www.joanganzcooneycenter.org/publication/stem-starts-early/

National Academies of Sciences, Engineering, and Medicine. (2016). *Parenting matters: Supporting parents of children ages 0-8*. Washington, DC: National Academies Press.

National Research Council. (2000). *From neurons to neighborhoods: The science of early child development*. Washington, DC: National Academy Press.

National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC: National Academies Press.

National Science Board. (2016). *Science and engineering indicators 2016* (No. NSB-2016-1). Arlington, VA: National Science Foundation.

Pattison, S. A. (2014). *Exploring the foundations of science interest development in early childhood* (Doctoral dissertation). Oregon State University, Corvallis, OR. Retrieved from http://hdl.handle.net/1957/54783

Pattison, S. A., & Dierking, L. D. (2017). *Early childhood science interest among low-income families: Variation in interest pathways and parent-child interactions*. Manuscript in review.

Pattison, S. A., Svarovsky, G. N., Corrie, P., Benne, M., Nuñez, V., Dierking, L. D., & Verbeke, M. (2016). *Conceptualizing early childhood STEM interest development as a distributed system: A preliminary framework*. Presented at the National Association for Research in Science Teaching Annual Conference, Baltimore, MD. Retrieved from http://www.informalscience.org/conceptualizing-early-childhood-stem-interest-development-distributed-system-preliminary-framework

Pattison, S. A., Svarovsky, G. N., Gontan, I., Corrie, P., Benne, M., Weiss, S., … Ramos-Montañez, S. (2017). Teachers, informal STEM educators, and learning researchers collaborating to engage low-income families with engineering. *Connected Science Learning, 4*. Retrieved from http://csl.nsta.org/2017/10/head-start-engineering/

Renninger, K. A. (2007). *Interest and motivation in informal science learning. Learning Science in Informal Environments Commissioned Paper*. Board on Science Education, The National Academies. Retrieved from http://www2.informalscience.org/researches/Renninger_Commissioned_Paper.pdf

Renninger, K. A., & Hidi, S. (2011). Revisiting the conceptualization, measurement, and generation of interest. *Educational Psychologist, 46*(3), 168–184.

Renninger, K. A., Nieswandt, M., & Hidi, S. (Eds.). (2015). *Interest in mathematics and science learning*. Washington, DC: American Educational Research Association.

Renninger, K. A., & Su, S. (2012). Interest and its development. In R. M. Ryan (Ed.), *The Oxford handbook of human motivation* (pp. 167–187). Cambridge, MA: Oxford University Press.

Rogoff, B., Mosier, C., Mistry, J., & Goncu, A. (1993). *Guided participation in cultural activity by toddlers and caregivers*. Chicago, IL: University of Chicago.

Sameroff, A. J. (Ed.). (2009). *The transactional model of development: How children and contexts shape each other*. Washington, DC: American Psychological Association.

Silvia, P. J. (2006). *Exploring the psychology of interest*. New York: Oxford University Press.

Stake, R. E. (2006). *Multiple case study analysis*. New York: The Guilford Press.

Svarovsky, G. N., Wagner, C., & Monica, C. (In press). Exploring moments of agency for girls during an engineering activity. *International Journal of Education in Mathematics, Science and Technology*.

U.S. Department of Education. (2014). *Hispanics and STEM education*. Retrieved from http://sites.ed.gov/hispanic-initiative/files/2014/04/WHIEEH-STEM-Factsheet.pdf

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. (M. Cole, Ed.). Cambridge, MA: Harvard University Press.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Los Angeles, CA: SAGE.

Zuiker, S. J., Anderson, K. T., Jordan, M. E., & Stewart, O. G. (2016). Complementary lenses: Using theories of situativity and complexity to understand collaborative learning as systems-level social activity. *Learning, Culture and Social Interaction, 9*, 80–94.

Notes

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[2] Head Start, administered within the Administration for Children and Families in the U.S. Department of Health and Human Services, provides services that promote school readiness among children under five living in poverty. Families are eligible to participate in the program if their household income is below 100% of the federal poverty line, they receive income-based public assistance, they are enrolling a foster child, or they are classified as homeless.

[3] In this paper, we use the term "parent" broadly to include any primary adult caregiver in a child's life, whether or not this adult is the biological parent of the child.