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Children's Engineering Identity Development Within an At-Home Engineering Program During COVID-19

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Abstract

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Keywords

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Children's Engineering Identity Development Within an At-Home Engineering Program During COVID-19

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Family "fasten[s] identity in place and keep[s] it from floating off…or losing its shape…" (Stone, 1988, p. 11).

Abstract

The culture of engineering and the culture of formal learning environments often make it difficult for individuals to develop an engineering identity. Conversely, recent research points to the home environment as an alternative setting to support discipline-specific identity development of children, while less is known regarding the identity development of children as engineers. Therefore, the purpose of this study was to explore the development of children's engineering identity through the co-creation of engineering concepts and engagement with engineering design thinking and processes with family members in home environments during the COVID-19 pandemic. We conducted interviews with nine families—nine parents and 13 children in Grades 3–6. Analysis of the interviews highlighted how situational interest, recognition, self-efficacy, and doing engineering shaped and informed children's developing identity. For example, child participants expressed heightened situational interest in the engineering design process and various genres of engineering, with some self-identifying as a particular type of engineer based on their interests. Some expressed greater interest in utilizing engineering practices and processes in the future, either as a career or as a hobby. As another finding, child participants discursively enacted and behaved as engineers through their experiences with collaboration, failure, and perseverance. Concurrently, parent participants articulated their child(ren)'s developing engineering identity, particularly in how their children conducted new processes and modeled the thinking and perseverance of engineers. Parents also noted the development of an inquisitive mindset regarding materials and objects in their home and community environments. We argue that the significance of this study lies in the potential to develop children's engineering identity in home environments beyond the pandemic, as well as inform children's identity trajectory as engineers as they continue to accumulate traces of an engineering identity over time and space.

Keywords: children, engineering identity, home environment, family engagement

Research has documented how the development of one's identity in a science, technology, engineering, and mathematics (STEM) discipline through early STEM learning experiences is associated with pursuing a STEM career (e.g., Cass et al., 2011; Dou & Cian, 2021; Dou et al., 2019; Godwin et al., 2016). This research implies that the development of young children's identity in engineering could lead to an increase in the number of individuals from historically excluded social identity groups pursuing engineering careers (National Science Foundation, 2021; Walden et al., 2018). However, the culture of engineering and the culture of formal learning environments often make it difficult for individuals with historically excluded social identities to develop an engineering identity because what it means to be an engineer is narrowly defined, often inundated with stereotypes, and at times constructed through limited and constraining opportunities (e.g., Carberry & Baker, 2018; Godwin & Potvin, 2017).

Research regarding identity in informal learning environments (e.g., STEM camps) has highlighted the positive development and trajectory of children as they begin to see themselves as STEM people (Simpson & Bouhafa, 2020). Recent research has documented STEM conversations with family and friends, particularly parents and siblings, as one of the most influential informal learning experiences in their early identity development (Cian et al., 2022; Dou & Cian, 2021; Dou et al., 2019). Informal learning experiences involving STEM media, participation in STEM groups/clubs/camps, and engaging in discipline-specific activities (e.g., tinkering with electrical devices) had less of an influence on identity development (e.g., Dou et al., 2019). Such research points to the home environment and family conversations as another, and perhaps an alternative context to support engineering identity development; an environment that diminishes barriers and access to STEM learning opportunities due to cost and cultural and structural inequalities (Dawson, 2014; DeWitt & Archer, 2017). Particularly for low-income and minority students, issues of access, affordability, and length of program/opportunity remain common barriers to inclusion, engagement, and identity development within STEM programming (Capobianco et al., 2011, 2012). Further, parents, regardless of their knowledge of engineering, are able to enact roles that support their child throughout the engineering design process as they have an intimate understanding of their child's strengths, abilities, and prior experiences (Cian et al., 2022; Dou & Cian, 2021; Simpson et al., 2021) and may be more comfortable with not having all the answers (Ellenbogen et al., 2004).

In this exploratory study, we sought to build upon scholarship that highlights the role of family[1] and home experiences in contributing to children's STEM identity formation (e.g., Dou et al., 2019; Morris et al., 2021; Rodriguez et al., 2021; Vedder-Weiss, 2018; Verdín et al., 2021), while also contributing to the scant literature that exists regarding the development of engineering identity with young children (Simpson & Bouhafa, 2020). The following research questions guided our study: (1) How did engaging in engineering design processes in the home environment during the pandemic support the development of children's engineering identity? (2) What were parents' perceptions of how their child(ren) developed and evolved as engineers through engaging in engineering design processes as a family unit in the home environment during the pandemic? Through this study, we argue that children are developing traces of an engineering identity through engaging in a program focused on family interactions and engineering design processes in their home environment. We contend that the significance of this study lies in the potential to develop children's engineering identity in home environments beyond the pandemic. The home environment serves as a familiar and place-based setting within a larger STEM learning ecology (Morris et al., 2019).

We begin by situating this study in scholarship regarding core elements for developing an engineering, mathematics, and/or science identity, as well as scholarship regarding identity development in out-of-school contexts. Next, we describe our theoretical framework and methodological process, including how the pandemic transformed our engineering program for children and their families. Following the results, we conclude by considering the similarities and differences of our results from prior scholarship and make recommendations for potential research.

Relevant Research

We acknowledge the complexity of measuring, conceptualizing, and defining a disciplinary identity (e.g., mathematics identity; Darragh, 2016). In this study, children's developing identity as engineers is a subjective notion of oneself within the social practice of engineering as developed through the affordances and constraints of the home environment and engineering program (Radovic et al., 2018; Vedder-Weiss, 2017). There is a vast array of internal (e.g., sense of belonging) and external (e.g., instructional norms) factors that positively and/or negatively inform children's identity development in a STEM field (Simpson & Bouhafa, 2020). For this study, we drew upon a body of research that has documented interest, recognition of self and others, and self-efficacy as being core elements for developing an engineering, mathematics, and science identity (e.g., Cass et al., 2011; Cribbs et al., 2015; Godwin, 2016; Hazari et al., 2010; Kim et al., 2018). In addition, Archer and colleagues (2010) found that children articulated their development of a science identity through "doing science" and "being a scientist" in their future careers. Weick (2004) referred to this as acting discursively. In this review of the literature, we utilized research across STEM fields and age ranges as the examination of young children's engineering identity is limited (e.g., Pattison et al., 2018; Simpson & Bouhafa, 2020).

[1] We recognize that families take on many forms. We use the term family to represent any consistent group of individuals living together, including nonrelatives and extended family members.

Interest

Research has consistently highlighted the direct effect of interest on an individual's identity in one or more STEM fields (e.g., Cribbs et al., 2015; Godwin et al., 2016; Hazari et al., 2010; Lock et al., 2019; Talafian et al., 2019). Due to the age of the children in this study, as well as the learning context, interest was narrowly defined as situational interest, the "likelihood that particular content, activities, or events will trigger a response in the moment that may hold over time" (Renninger & Su, 2012, p. 169). While teachers play a primary role in interest development and maintenance at the secondary (e.g., Grades 6–12) and post-secondary years, parents have been identified as playing a significant role in triggering and supporting their child(ren)'s interest in STEM when children are younger in age (Dabney et al., 2013; Maltese et al., 2014; Sha et al., 2016). For example, Maltese and colleagues (2014) found that 29% of their adult participants reported parents as the individuals who sparked their interest. Similarly, Sha et al. (2016) found that creating a family support environment in which children felt their learning was supported had a direct effect on their STEM interest. Therefore, this research supports the consideration of interest on children's engineering identity development through engagement with their family and/or within the context of their home environment. Conversely, interest in engaging with and/or learning more about science (or another STEM discipline) does not necessarily translate into an interest in being a scientist (Archer et al., 2010; Wade-Jaimes et al., 2021).

Recognition

Recognition in this study is viewed as seeing one's self as an engineering person (Carlone & Johnson, 2007), as well as one's perception of how others (e.g., family members, peers) see one as an engineer (e.g., Hazari et al., 2010; Hill et al., 2018). When negotiating and performing recognition work, individuals should act, think, and behave in ways that others will recognize them as an engineering person within a social context (Brown et al., 2005; Gee, 2000), or not, as their goal may be to be recognized as a non-engineer (Zimmerman, 2012). Quantitative scholarship has consistently highlighted recognition by others to be one of the strongest constructs associated with one's STEM identity (e.g., Cribbs et al., 2015; Godwin et al., 2016; Hudson et al., 2018). For example, utilizing structural equation modeling, Godwin et al. (2016) found the factor loadings of math and physics recognition had twice as large a direct effect on identification as a math person or physics person than interest and performance/competence beliefs. As noted by Wang and Hazari (2018), there are explicit and implicit strategies that can be utilized by educators in regard to an individual's identity development such as language and behaviors that promote agency and build a sense of trust in one's ability to learn concepts. Hence, this research highlights the importance of providing external acknowledgments (not praise) and support in developing one's identity (Cribbs et al., 2015; Hazari et al., 2017; Hughes et al., 2021), which includes recognition from family members (Rodriguez et al., 2019).

Recognizing one's self as a discipline-specific person (e.g., mathematician) has also been shown to shape an individual's identity (e.g., Carlone & Johnson, 2007; Rodriguez et al., 2019). In a study by Carlone and Johnson (2007), the recognition of self as a science person by 15 women was framed through a love of science and interest in research and/or through unselfish concern and interest in humanity. Quantitatively, researchers may include at least one item that asks participants to identify themselves as a particular person (e.g., "I see myself as a physics person"; Godwin et al., 2016).

Competence and Self-Efficacy

Competence is defined as one's beliefs regarding one's ability to understand concepts (Carlone & Johnson, 2007). Two factors, competence and performance, have consistently loaded together when examining an individual's discipline-specific identity (e.g., Cass et al., 2011; Hazari et al., 2010). Quantitative studies have often concluded a small, insufficient (Cribbs et al., 2015), or negative effect on identity development (Godwin et al., 2016; Lock et al., 2019). Scholarship has consistently shown competence to have a positive indirect effect on identity when mediated through interest and recognition (e.g., Cribbs et al., 2015; Godwin et al., 2016). Therefore, competence alone is more than likely not enough to positively inform one's identity development, but the more strongly one believes in one's ability to understand engineering concepts, the more likely one is to be interested in engineering and believe that others see one as an engineer, respectively.

In this study, we focus on self-efficacy as opposed to competence as families are engaged in engineering tasks over a short amount of time. It is not likely that these tasks would shape the children's beliefs regarding their ability to understand engineering concepts. Self-efficacy, as noted by Godwin (2016), is closely aligned with students' competence/performance beliefs, while Zabriskie and colleagues (2018) argued that self-efficacy may be a precursor of competence. Yet, self-efficacy is more narrowly defined as one's belief regarding one's ability to perform a specific task (Bandura, 1997) and is discipline-specific (Robnett et al., 2015; Zabriskie et al., 2018). Therefore, engineering self-efficacy reflects one's beliefs regarding the likelihood of completing an engineering task or project successfully. As such, prior research highlights self-efficacy as a significant predictor of one's identity development in STEM (Buontempo et al., 2017; Flowers III & Banda, 2016; Robnett et al., 2015; Zabriskie et al., 2018). For example, Buontempo and colleagues (2017) found self-efficacy to be a significant predictor of students' engineering identity while enrolled in a high school engineering course.

"Doing" Engineering

In this study, doing engineering is defined as discursively describing ways of enacting practices and processes of an engineer. Similar to Danielsson (2012) and Martin and Betser (2020), we contend that through this project, children are not only acquiring the knowledge, routines, skills, and practices to do engineering but also learning to be an engineer as articulated through individual narratives. For children, their doing of engineering is often framed, or constrained (Stonyer, 2002), within an engineering design cycle such as ask, imagine, plan, create, and improve (Museum of Science, 2021) or as part of school curriculum that defines what it means to engage in age-appropriate engineering practices (Capobianco & Rupp, 2014; NGSS, 2013). As research regarding children's doing engineering through discursive practices is limited, we turn to scholarship that examined children's views of what it means to do engineering and be an engineer as such ideas and beliefs become infused with their engineering identity (Archer et al., 2010).

Children typically have a limited understanding of what the doing of engineering entails. Common conceptualizations of engineers include mechanics, laborers, and technicians whose work consists of fixing, building, and working on things utilizing materials and objects such as blueprints, computers, furniture, and safety gear (Capobianco et al., 2012; Karatas et al., 2011; Oware et al., 2007). Less frequently are the actions of engineers portrayed or described as designing, inventing, creating, or planning a product (Karatas et al., 2011). Further, engineering design is considered a two-step process—planning to a final prototype (Karatas et al., 2011). However, research has shown that it is possible to shift children's conceptions of engineers and engineering through engaging them in engineering curriculum experiences (Capobianco & Mena, 2013; Newley et al., 2017; Utley et al., 2020). For example, after implementing an engineering curriculum intervention, students in Grades 2–4 more often viewed engineers as designers as opposed to a mechanic or a driver (Carr & Diefes-Dux, 2012). Therefore, it is possible for children in our program to rethink their doing of engineering through engaging in engineering tasks with family members in their home environment, which will shape and inform their developing engineering identity (Archer et al., 2010). As such, Capobianco and colleagues (2012) have developed a list of attributes that should inform children's conceptualization and understanding of engineers such as being creative, using mathematics, designing things around us, and solving problems to help others.

Theoretical Grounding

This study is grounded in the theoretical perspectives of identity and its development as a contextual and iterative process (Wenger, 2010). Previous research notes that the genesis of one's identity is dependent upon both intrinsic characteristics and external, interactional elements such as dialogue, tactile experiences, and working with others (Lave & Wenger, 1991; Wenger, 2010). The interaction and dialogue that emerges between individuals in a group subsequently informs how an individual sees themselves and others (Gee, 2000). Through such social exchange and an uptake of contextual and environmental factors (i.e., learning settings), an individual ultimately comes to identify as one type of person or another in relation to those they are around, their interactions, and where they are located (Gee, 2000).

These social and situational factors so crucial to identity development were further expounded by Wenger (2010) and represent key elements within their conceptualization of identity trajectories. In this sense, one identifies who they are by relating their identities to where one has been (or what one has known) and where one is headed (or what one hopes to know) (Calabrese Barton et al., 2013; Wenger, 2010). Wenger (1998) argued that identities as trajectories continually incorporate both past and future sense of self in tandem with one's immediate experiences or environment. It is through this iterative process that an individual inherently selects "…what matters and what does not, what contributes to our identity and what remains marginal" (Wenger, 2010, p. 134).

It is this perspective that informs our thinking in the current study and aids in our conceptualization of participating children seeing themselves as novice and developing engineers. In this study, as children articulated what they knew and how they viewed themselves as engineers in the program (i.e., present) in relation to their past and their future selves, we observed seeds of their identity as a constant becoming or moving along a trajectory (Avraamidou, 2019; Lave, 1991). Calabrese Barton and colleagues (2013) described this process of identity trajectories as an accumulation of traces or reified moments that are socially accepted or rejected. The situational interest, recognition, and actual engagement with engineering concepts contributed to continuous changes in self-perspective as an engineer over time and place. As exemplified by Gonsalves et al. (2021), trajectories into a particular field are nonlinear and complex; yet, early experiences (or lack of experiences) in out-of-school learning contexts shape and inform students' narrated trajectories as undergraduate students pursuing a degree in a STEM field.

Methods

Program Description

Prior to the pandemic, we developed and implemented a program that included monthly in-person sessions with families to introduce and engage in the engineering design process through a self-identified problem. The prompt was as follows: "What problem(s) or issue(s) are you interested in engineering a solution for? Think about problems in your home, your school, or your neighborhood. Or think about someone you know that might need something created to help them with an aspect of their life." These monthly sessions lasted approximately two-and-a-half hours and occurred in a community-based site, namely a local church and public library. Undergraduate engineering students, as well as engineers working in a local industry, volunteered to attend these sessions and support families through the process. Similar to the program structure of Roque (2016), these sessions were typically divided into four parts: Meet, Eat, Design, and Share. Between monthly sessions, families were provided with a researcher-developed engineering kit. The kits were framed around an engineering problem and included all the materials and tools necessary (see Simpson & Maltese (2019) for more information).

The impact of COVID-19 raised questions as to how to alter the program so families were self-reliant and engaged as engineers through design processes and practices in their home environments with limited support and interactions with members of the research team and volunteer engineers outside virtual gatherings. We decided to alter our approach to include two phases—engineering kits followed by the self-identified problem/issue—as opposed to an integration of the two forms of engagement prior to the pandemic. We believed this decision would allow families to gain an understanding of the engineering design process and enact actions and behaviors of engineers before defining and developing a solution to their own problem (i.e., being self-reliant).

We made substantial changes to the engineering kits including a facilitation guide to support parents as educators. See our project website at https://athomeengineers.com for access to the kits and guides. The supports included open-ended questions to pose to their child(ren) during the process, connections to math and science concepts, troubleshooting tips, and images that detailed how things worked (e.g., simple circuits). Another change was encouraging families to supplement materials in the kit with items around their home including recyclable materials and items in a junk drawer. In addition, we created engineering passports with the goal of developing career awareness of different types of engineers that aligned well with our engineering kits (e.g., automotive, biomedical, civil). Another goal of the kits was to develop children's identity as an engineer as they were asked to "…place a sticker from the kit on the passport page that identifies which engineer you felt that you were most like while completing the kit. Then, write a few sentences explaining how you talked and/or acted like that engineer." During the pandemic, kits were delivered to individual family doorsteps approximately once a month between January and April.

As the project transitioned from the kits to their personal engineering projects, we developed a self-paced slideshow that included researcher-developed example projects and videos of the engineering design cycle (see slideshow). From May to June, families worked to identify a problem or project, brainstorm various solutions, and then design, test, and modify prototypes. As an example, one family developed a "soap dispenser that will use all the soap. A lot of times when it gets to the bottom, the straw cannot reach that last bit of soap…and mom usually adds water." They utilized materials in their homes such as plastic bottles and food containers, glue, and a relatively empty soap dispenser.

The last change to our original project was the transition from in-person meetings to virtual meetings. We held an optional show-and-tell meeting once a month, but at two different times, Thursday night and Saturday morning, to accommodate varying family schedules. Meetings were structured to engage families in talking about their process and engagement as engineers in the kits, as well as to talk about their self-identified projects and receive feedback and advice from others. One way we facilitated the discussions was through online engagement tools (e.g., Kahoot) and interactive slideshows (e.g., researcher-developed Bingo) that children and parents were familiar with (see slideshow for an example). We also offered weekly office hours every week, but these were rarely attended beyond the first two weeks.

Participants

Potential family participants were recruited in collaboration with five local school districts. Every family with at least one child in Grades 3–6 was sent brief information along with a short video introducing ourselves, showing the engineering kits, and presenting highlights of the program (e.g., free, home delivery). This information was disseminated through SeeSaw posts, email from teachers, or through social media from the school district. We met virtually with every family that expressed interest to provide more specific information about the program (e.g., dates) and the research study. We followed up with an email asking for consent and assent.

We conducted semi-structured interviews with nine families, 13 children (nine females, four males), and nine parents (six females, three males). The self-identified ethnicity (and intersectionality) of the child participants included two African Americans (females), one Asian (female), one Biracial (female), and eight Caucasians (five females, four males). There were several reasons provided by parents as to why they decided to participate in this program. The main reason given was to provide their children an opportunity to engage in hands-on STEM activities as similar opportunities in the local area are not age-appropriate or free. Another reason was to supplement at-home education during the pandemic. Table 1 includes demographic and other information regarding family participants. Participant-created pseudonyms are used to maintain anonymity. Household incomes are above the poverty level and participating parents had a professional career, including a career within the field of engineering.

Data Source

The primary data source was semi-structured interviews with children and at least one parent, while secondary data sources included family-recorded videos shared through the Sibme app (2021), as well as show-and-tell virtual meetings. The videos and virtual meetings were utilized to contextualize the interview data as opposed to confirming findings from the analysis of interview transcripts (Jocius et al., 2020) as identity in this study is a subjective notion of oneself. Interviews took place at the conclusion of the program in June 2021. Child interviews and parent interviews were conducted separately. Together, the interviews lasted approximately 30 minutes and were conducted either through a virtual platform or in-person (e.g., family home, public park) based on family preference. More specifically, we conducted five interviews virtually and four interviews in-person. The interviews were either video-recorded or audio-recorded, respectively, and transcribed verbatim. The interview protocol for children was framed to investigate their developing identity as an engineer through the co-creation of engineering concepts and engagement in engineering practices and design thinking with parents and other family members in their home environment.

Child interviews consisted primarily of posed statements, with which participants could agree, disagree, or state a neutral stance, followed by probing questions and requests for an explanation of their response. Example statements include (a) I would often stop when something did not work well, (b) I see myself as an engineer, (c) My family sees me as an engineer, and (d) I would like to learn more about engineering (see Appendix A for the interview protocol). If an explanation and/or example were not provided, we would ask the children to provide an example from the program. This decision was based on child interviews from the previous year. The inclusion of open-ended questions was not fruitful as child participants had a difficult time articulating their thinking; therefore, we narrowed the scope of their focus. The interview protocol for parents was similar to the questions posed to parents and guardians the year before. Example questions to parents included (a) What did you notice in terms of (child's name) development as an engineer in this program? How did it change from the beginning of the program? and (b) How did your interactions with [child(ren)'s name(s)] change? Why? How might this have been impacted by their development as an engineer? Refer to Appendix B for the parent interview questions relevant to this study.

Data Analysis

Child and parent interviews were analyzed by hand by both researchers. We found value in coding all interviews individually and discussing our agreements and disagreements of codes and emerging patterns as opposed to establishing interrater reliability and analyzing interview data independently of one another. First, we coded the child transcripts using *a priori* codes of interest, recognition, self-efficacy, and "doing" engineering. Next, we compiled direct quotes from each individual *a priori* code together to search for emergent or recurring patterns that highlighted their developing engineering identity (Saldaña, 2014). Through this process, *future self* emerged as a code. *A priori* and emergent codes are highlighted in Table 2.

Following the analysis of the child transcripts, the first author analyzed parent transcripts using an iterative and inductive approach (Saldaña, 2014). First, descriptive codes were assigned to capture the essence of parents' responses regarding how they viewed their child(ren)'s developing identity as an engineer. For example, *resourcefulness* was an initial code given to responses that indicated how engagement in the program shifted how children used materials and objects in and around their home environment. The initial codes were given to the second author as a way to refine the initial codes (Saldaña, 2014). Through this process, *resourcefulness* was combined with other descriptive codes to create *outside-the-box thinking*.

Table 1
Description of family participants.

Child pseudonym	Age	Gender	Ethnicity	Participating parent pseudonym	Gender	Highest level of degree	Self-described career	Household income range	Participated in similar program
Sam	13	M	White	Sally		Bachelor's + 15	Writer	$50,000–$75,000	Yes
Jake	11	M							
Annie	11	F	Bi-racial	Angela	F	Master's	Social work	$75,000 or above	No
Jonathan	10	M	White	Jennifer	F	Bachelor's	Home maker	$75,000 or above	No
Courtney	10	F	White	Kim	F	Master's	Aerospace electronics systems design	$75,000 or above	No
Garrett	8	M		Mark	M	Master's	Aerospace electronics systems design		
Beth	9	F	White	Jake	M	Bachelor's	Software engineer	$75,000 or above	No
Kirari	9	F	Asian	May	F	Master's	Education	$75,000 or above	Yes
Eve	10	F	White	Martha	F	Bachelor's	School nurse		No
Ashley	10	F							
Eleanor	10	F	White	Tod	M	Bachelor's	Software development	$75,000 or above	No
Helen	11	F	Black	Rachel	F	Master's	Disability services	$50,000–$75,000	No
Joy	8	F							

Table 2
A priori and emergent codes for child and parent interviews.

Child interview codes	Parent interview codes
Situational interest • Process in engineering design cycle • Disciplinary concepts • Field of engineering	"Doing" engineering • Enacting the engineering design process • Perseverance through failure • Collaboration
Recognition • Recognition of self • Recognition from others	Inquisitive mindset • Outside-the-box thinking • Curiosities and questions
Self-efficacy	
"Doing" engineering • Enacting the engineering design process • Perseverance through failure • Resourcefulness • Collaboration	
Future self	

Position Statement

Researchers' identities and positionality serve as a lens for how they view and interpret our social worlds, as well as understand their relationships with the research context, participants, and data (Corlett & Mavin, 2018; Jacobson & Mustafa, 2019). The first author is a White, middle-class female and mathematics education professor; therefore, an outsider to the discipline of engineering. Her research lies broadly in STEM education in out-of-school and hybrid (i.e., informal spaces in a school context) learning environments, including a focus on identity work. This is the first program in which the first author has worked with families. She co-developed the program and engineering kits. As a child, the first author cannot recall engaging in a similar experience with her own family.

The second author is a White male and doctoral candidate at the time of the study. His areas of research involve family engagement and school–community partnerships; however, this was his first programmatic experience in a STEM-specific context. As a White male and an outsider to the discipline of engineering and STEM, in general, he has made considerable efforts to reflect and prioritize introspection around his own experiences engaging with STEM concepts and materials. He also cannot recall engaging in this type of STEM-related activity as a child, with his family. We acknowledge how our multiple perspectives and experiences are both strengths and weaknesses to the program and interpretation of the results. Through discussions and exchange of ideas, we work to identify and mitigate implicit biases and misperceptions regarding engineering and identity development in children, particularly through familial experiences.

Results

As noted in the theoretical grounding, it was not expected that children in this study would possess a salient or solidified engineering identity (Wortham, 2008), but that they developed fluctuating components or traces of an engineering identity that will have enduring and accumulating effects on their identity trajectory as engineers (Calabrese Barton et al., 2013). We illustrate this point with one child participant before presenting results across child participants. Next, we highlight how engaging in engineering design processes in the home environment supported the engineering identity development of the child participants. Then, we discuss parents' perceptions of how their child(ren) developed and evolved as engineers through engaging in engineering design processes as a family unit in the home environment. We provided representative examples and quotes to substantiate the results of our analysis.

Identity Trajectory Vignette

As part of the program, Beth and her family completed six kits. Their self-identified family engineering project was to design and prototype a "soap dispenser that will use all the soap. A lot of times when it gets to the bottom, the straw cannot reach that last bit of soap." In the interview, Beth often used the word *like* to express her situated interest in engineering, particularly in building and designing prototypes, as well as in learning more about the different types of engineers. As an example of the former, Beth stated, "I liked building it [friendly delivery kit] and it ended up to be pretty cool and I really

Figure 1. Snapshot of Beth delivering a package to her sister.

liked the design." In essence, Beth and her family created a pulley system and a platform out of the material provided to deliver a "package" between two chairs (see Figure 1).

Further, Beth expressed being more like an engineer than at the start of the program as she learned more about engineers and how they build things. She articulated several examples in which she performed actions and behaviors of an engineer, particularly in the engineering design process (e.g., redesign) and in her experiences with failure. Consider the following quote from Beth's interview:

> That one [grabber] had a very big problem. It didn't really work at all. What we first tried to do was we put a string in a binder clip and we had our cups that open and shut, and it would just go crazy. You couldn't control it. It would just flop over to one side or another because the string was too small and it wasn't filling up the space. So after that, we tried to do rubber bands, but the rubber bands were too stretchy so it would take you forever to pull it [see Figure 2A]. So we ended up just changing that to the scissors one [see Figure 2B] and that one, we still have it and it works pretty well.

Beth's belief in her ability to complete a task (i.e., self-efficacy) was coupled with support from others, particularly her dad. As noted by Beth, "He [dad] helps me with usually the main idea and what we're gonna do and he does most of the hard parts like cutting with knives or scissors." Further, her self-recognition as an engineer was "probably in the middle 'cause I'm not a perfect engineer." This sentiment was further expressed in Beth's recognition from her family as "they would just think of me as maybe an engineer." She noted this was due to her lack of experience as an engineer and because some of her prototypes did not work out. Lastly, in negotiating her future self, she liked the idea of being a civil engineer, but still leaned toward pursuing a career as a vet or a doctor. In reflecting on her experiences in the program, Beth's

Figure 2A Figure 2B

Figure 2. Snapshots of Beth's iterations of the grabber prototype.

developing engineering identity was composed of shifting and dynamic components from the beginning to the end of the program (e.g., experiences with failure). Furthermore, her present experiences and developing identity as an engineer were framed within her future self (i.e., vet or doctor).

Research Question 1

Situational Interest

Children's situational interest was grounded in the different engineering kits, and as a collective, spanned different processes within an engineering design cycle—ideation process (Garrett), drawing out ideas (Eleanor), designing and creating prototypes (e.g., Joy, Jerome, Hannah), and testing the prototype (Courtney). As stated by Courtney,

> I liked the testing part of the thing [grabber] where you have to hold something… And I also liked the shelter for the pet because I liked seeing the different changes [in temperature] from when we first put it out there, and from when it was out there for a while.

For Eve and Ashley, their interest in prototyping was based on engineering challenges that allowed them to create and construct the prototype in the process (e.g., paper roller coaster) as opposed to challenges that they expressed as planning the prototype in advance (e.g., trendy tennie). Below is an excerpt in which Eve and Ashley described this in-the-moment process of their amusement park (see Figure 3).

> Eve: We planned some of our roller coasters, but then we're just like, "Oh, I got an idea," and just started putting it together.
> Ashley: Yeah, we used LEGOs to make it… It's called The Twister from a LEGO set. So we basically just taped two pieces of paper onto it. We made a box out of the square pieces… A square box, and taped it to it, and make it like an amusement park ride. And we also did more than just that. We made…zero gravity roller coaster thing…
> Eve: Like where you get lifted up into the air and it just feels like you're flying.
> Ashely: Well, at first, I was gonna make it a seesaw, but then it wouldn't work because we didn't have a… What is it called? A pivot? I think it's called a pivot. So, I decided to bend it a little bit more and put two pieces of string. I made it go up 'cause you pull it up, and it makes it like a zero gravity roller coaster thing.

This in-the-moment process was similar to Jake's in that his situational interest in creating prototypes was amplified when engaging in kits that afforded him more creativity and freedom. Jake provided the friendly delivery kit as an example as it provided several options for delivering a package (e.g., airplane, catapult). As these examples from child participants highlight, situational interest in creating and testing the prototype was most common. Children were less interested in planning—researching, brainstorming, and sketching out possible solutions. This was expressed by Jonathan:

Figure 3. Snapshot of Ashley and Eve's amusement park developed from the paper roller coaster kit.

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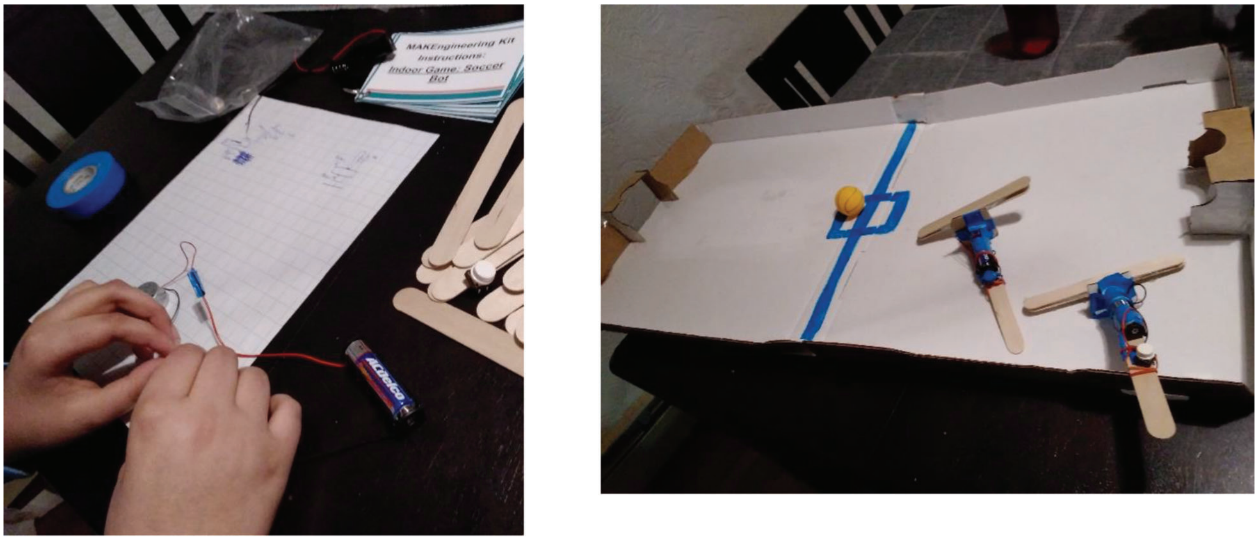

Figure 4A Figure 4B

Figure 4. Snapshots of Annie's creation of a simple circuit for the soccer bot kit.

> After the planning part, it's kind of fun… I only like planning once I have a clear idea in my head. Because I have to brainstorm like a million things. Then I have to research those million things. And then I have to pick which one, which I have a hard time doing.

Another example of situational interest mentioned by four children was their growing interest in disciplinary concepts, namely circuits, and the field of engineering in general. For example, Annie expressed, "It was cool putting together the circuits… I became interested in general electricity and the way it works. I just think it's really cool, just how it's created and how it's so efficient." Figure 4A is an image of Annie creating a circuit for the soccer bot with Figure 4B highlighting her final prototype.

As another example, Kirari expressed interest in circuitry prior to this program, but the rain gauge kit supported the maintenance of Kirari's situational interest in circuity as she articulated developing knowledge of the concept. "After I did the rain gauge, I knew even more. I learned about like when there's a circuit, you can't have anything blocking the conductor because then it won't work." All the children in this study expressed an interest in learning more about the different types of engineers and the engineering field. In one instance, Joy noted the following: "Well, engineering is to help and make and improve on different things. So I wanna learn more about how to do."

Recognition

Each child was able to identify themselves as a particular type of engineer. For Eleanor, she identified as a biomedical engineer because she enjoyed the kits in which she built things to help others. Eve identified herself as a civil engineer because she liked the "idea of building things like the roller coasters or bridges or even houses." And Jerome and Annie both identified as electrical engineers because of "making stuff with electricity" and "it's fun for me to look at circuits," respectively. Children's explanations of being a particular type of engineer seemed to be informed by their interests developed as part of the engineering kits. Generally speaking, the majority of children in this study recognized themselves as engineers, and oftentimes this was informed by their engagement in the kits and/or the engineering passports. This was expressed in several ways: (a) "…because when I'm doing the kits, I have to solve things, like problems" (Kirari); (b) "…we were doing stuff from pretty much like scratch and with the materials we had to use, we were making inventions" (Courtney); (c) "…with coming up of my own ideas. Not exactly what the directions of the kit said. We kind of went a little to our own way" (Eve); and (d) "With the kits, you are the one that was working towards a goal and it was on you if it didn't work out" (Jake). These quotes not only illustrate how engagement in the project shaped their self-identification as an engineer but their reasoning was grounded in some part of the engineering design process, as well as developing a sense of agency as an engineer.

The majority of children in this study agreed that members of their family—parents and siblings—viewed them as an engineer (i.e., recognition from others). As stated by Courtney, "I think my parents would see me as an engineer working on the projects and stuff…as them themselves being engineers, they would probably know like what engineering is truly like." Garrett, Courtney's brother, agreed. "They probably see us as an engineer in doing the engineering projects and like other stuff…in math they also probably see you as an engineer." This sense of recognition was more often situated within a specific component of the engineering design process. In particular, recognition from others was often part of brainstorming ideas and creating a prototype, and less often in their ways of thinking or using material or drawing sketches and designs. For example, Eve perceived her sister Ashley viewing her as an engineer because she was creative with her ideas while Ashley perceived her sister as describing her as an engineer good at building things. Conversely, four of the children in this study expressed doubt as to whether or not family members recognized them as an engineer. As noted above, Beth was unsure due to her lack of experience as an engineer. Similarly, Joy teetered between agree and disagree based on whether she was able to figure out why something was not working as expected or not. For Elizabeth, she quickly stated, "I don't think my dad does because he is an engineer." Lastly, Sam questioned whether his brother, Jake, recognized him as an engineer because "I'm not sure if I see myself as one."

Self-Efficacy

Children's self-efficacy as an engineer was often framed as a cyclical process in that as they gained skills, knowledge, and practices, their beliefs in completing an engineering task increased. Annie expressed a change in her efficiency in building prototypes. "I'm a little bit more efficient. Last year I struggled sometimes putting things together, and now I'm a little bit more like, 'Oh, this would go up here and this would go up here.'" There was a sense of confidence in her ability to complete engineering tasks, particularly in that "I easily put everything together once it was designed." To continue, Annie's self-efficacy extended beyond the program itself to how she viewed the world as a developing engineer. As stated by Annie, "Yeah, certain problems I do think, 'Oh, I could probably fix that if I engineered a solution to it.'" As another example, Courtney reflected on their ability to take the provided objects and materials and create something new.

> But when I was doing the project, I kinda felt good that I could do it. So, when we were doing it, like Garrett said, we were doing stuff from pretty much like scratch and with the materials we had to use, we were making inventions, which made me feel good that we could create something from something else, like the toy hack. We could use a toy to create something else.

As seen in Figure 5, Courtney and Garrett, in collaboration with their parents, transformed what they determined to be spy gear binoculars into a survival kit.

Doing Engineering

Throughout the interviews, children articulated how their engagement with the kits and/or their self-identified problem afforded them opportunities to enact the processes and practices of engineers. For example, Annie noted her enactment as an engineer was through her actions and behaviors in an engineering design process. "I actually acted like an engineer where I saw a problem and I thought of a solution to fix it and then design it, and build it and went through the whole step by step process to build something that could help people." Yet, the most common way children expressed doing engineering was through their experiences with failures, defined by Annie as "I thought it would work, and it didn't." Children were able to provide specific examples to illustrate. The following example from Kirari exemplifies the process of iteration or improving the quality and functionality of her paper roller coaster based on her interpretation of the failure:

Figure 5A

Figure 5B

Figure 5. Transformation of spy gear binoculars into a survival kit.

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> I made like a jump. I made a like a space between the other part of the roller coaster, and it [marble] was supposed to jump, but then the ball wouldn't jump much and then it wouldn't go to the other side. So I ended up putting some kind of like triangle thing, so that if the ball falls and it goes in there, you could take it back out and then you can try again, but then when I didn't add it [triangle], it [marble] just rolled over and then I had to find it.

For Kirari, experiences with failure were framed as "solving a mystery." During the interview, Courtney thought through ways to make improvements to the animal house that was "finished" several months prior. Her brother Garrett noted, "With that one, we did not keep it warm because the inside was colder than the outside." Courtney added, "Well, I would probably use like carpeting, 'cause I feel like that would keep it nice and cozy in the inside and maybe thicker walls instead of cardboard to make it more sturdier and more warmer." As such, children expressed how experiences with failure led to feelings of frustration where their strategy was often to pause for some time before revisiting their prototype; thus, their doing of engineering included perseverance. As expressed by Jonathan,

> I get frustrated… I sometimes took breaks, including when we were doing it. I had this kit where I made a roller coaster, and it wouldn't work for me. So, I took a break and I came back and I understood it more.

As noted in this quote, walking away was a strategy that afforded Jonathan clarity when he returned to his prototype. Similarly, Helen framed such moments as a growth point. "Well, so far I've learned that you can take a step back and look and reanalyze and improve on different things."

Doing engineering was also articulated as seeing and using materials and tools differently—being resourceful. This was particularly the case with recyclable material and adhesives such as tape. For example, Annie stated, "I didn't realize how useful it [cardboard] could be for such things, and tape. I didn't realize how much you could use tape in just random things that would actually work effectively." Figure 6 is illustrative of Annie's use of cardboard and tape in creating a prototype for their self-identified problem, namely to figure out a way to secure their garden that was falling apart.

Annie's shift in perspective was likely due to the materials and tools included in the kits being "just necessary" to create a prototype. Sam and Jake viewed this as a limitation or a constraint that then made them question "what kind of resources and materials can we grab from around the house to modify it and make it work." Kirari even noted how she gained an understanding of how different adhesives and materials worked together to create a functional prototype. The following example highlights Kirari's understanding of the useful properties of hot glue:

> I think the hot glue is not very good at paper, because paper is like you can bend it and fold it, and you can move it. But then I think it's good for plastic and cardboard because they are more stiff and they won't move much, then you can glue things on them.

Figure 6. Annie's garden prototype.

Lastly, for child participants doing engineering was situated as a family, or a collaborative, endeavor. For instance, Courtney stated, "We each came up with separate ideas…we thought over each idea and thought how it would work and we did all the cons and the pros. We took all the pros of each of our ideas and combined them." Similarly, Jonathan expressed how support from his mom and dad in the brainstorming ideas made the process "a little bit easier" because "sometimes a lot of people have an idea, but they can't do it without other people." Collaboration was also a part of creating and re-creating the prototype as some of the projects required multiple hands as expressed by Ashley and Eve:

> Because we needed someone to help hold the wires, and we needed someone to tape the wires together, and we needed someone to glue the stuff so it wouldn't fall out. So, we were kind of all doing it at the same time so all the wires wouldn't fall all over the place.

Helen described the creation of the prototype as a shared experience in which each individual in the family would take "different shifts…everybody got a turn doing each thing." The example provided by Helen was the use of the hot glue gun in securing LED lights in a plastic cup. For siblings in particular, collaboration afforded them opportunities to recognize and utilize one another's strengths within the various engineering design processes. As stated by Jake, "Sam was good at coming up with ideas and how to change around the ideas that we had. And I feel like I might have occasionally had more of the hands-on."

Future Self

Four of the children in this study expressed some interest in being and becoming an engineer (i.e., future self). For example, Annie said, "I could see myself being an engineer and designing things that would help people or something. I think it would be cool for me to grow up and design things and build things and do things like that." It was more common for the child participants to frame their future selves as utilizing engineering processes and practices as part of their job or as a hobby because there is more freedom to build and design what they want as opposed to being bound by the constraints of others. Garrett, for instance, acknowledged the likelihood that he might have a career that included aspects of engineering. "There's a bunch of different jobs that don't have engineering in. And some jobs do have engineering in. So, I might end up doing something with engineering." Eve provided a specific example of the latter. "I would like to do robotics when I get older, but I don't know if I'd actually wanna be an engineer because I have to design a certain thing."

Research Question Two

The purpose of this question was to understand parents' perceptions of how their child(ren) developed and evolved as an engineer through engaging in engineering design processes in their home environment during the pandemic as this may have implications for the different components shaping children's engineering identity (e.g., interest, recognition).

Doing Engineering

One, parents described their child(ren) as developing an identity as an engineer particularly in how they enacted the processes of and modeled the thinking and perseverance of engineers (i.e., identity as a performance; Darragh, 2016). For instance, Angela described how the program has impacted her daughter.

> I feel like everything is an engineering idea now. I feel like it opened up her ways of thinking. Like she'll be clicking a pen and then five seconds later I look over and the pen will be apart and she'll be like, "Mom, look at this cool mechanism" or "what do you think of this?" And I think it just helped her think of the world differently, so yeah, I could totally see her being an engineer now. I think veterinarian is out, engineer is in.

Parents acknowledged how the kits provided the foundation for their child(ren) to know a process that was common to engineers. It was through this process that parents observed their children engage in planning as opposed to immediately prototyping, conducting research, innovating through iteration, and communicating their ideas and thinking more clearly. As an example of the latter, Kim described a moment that stood out to her after testing their grabber. "I just remember them [Courtney and Garrett] being able to articulate what happened during the testing and what we would do next time."

The most common experience noticed and expressed by parents was their child(ren)'s experience with failure and frustration moments. As stated by Martha,

Figure 7. Snapshot of Eleanor's gutter system on her animal house prototype.

> They [Ashley and Eve] had a couple of things that they had and it just wasn't working, so they had to totally disassemble, cut the glue apart, take things all apart to start over with something else just because it didn't work. Even though you spent a lot of time on this one thing. Not everything is cut and dry.

This quote also highlighted children's perseverance when a prototype did not work as expected. Rachel too noted Joy and Helen "wanting to do it over and over again." Video data supported this as well as Joy and Helen made seven changes to their rain gauge with the last prototype still not working appropriately.

Collaboration was also expressed as a practice that children developed as part of the program, particularly when working with a sibling. When asked how Garrett and Courtney had changed through the program, Kim noted an evolution in their cooperative behavior, which is "probably tougher with siblings to…that collaboration." Sally expressed this as dividing up roles. "I thought they [Sam and Jake] did a really good job dividing up the roles. I didn't see them argue a whole lot…they worked pretty well without me." As the two quotes imply, working alongside a sibling can be difficult, but through this program, siblings exhibited collaboration with one another. As another example, Martha described how Ashley and Eve learned how to merge ideas together:

> We ended up with two different ones [DIY grabbers] because one wanted it this way and one wanted it this way, and then we kinda had to take everybody's suggestions to put everything together with both of them. Not just I want one this way and one this way.

Rachel framed this growth as teamwork as they would take turns in completing particular parts of the prototype such as gluing material. She further expressed being inspired by Joy and Hannah's collaboration as there were times when she became frustrated and walked away while Joy and Hannah would sit and troubleshoot problems with the prototype together.

Inquisitive Mindset

Parents also noted the development of an inquisitive mindset regarding materials and objects in their environment (e.g., home, community). In particular, parents often expressed how the kits supported their child(ren)'s outside-of-the-box thinking about how to use materials. This is captured in the following quote by Jake, Beth's father: "She started not just seeing the materials for what they were and what their practical uses were, but what they could become." This included recyclable material, as well as everyday objects (e.g., pens, lifesavers) and structures (e.g., dams). May, for instance, described how Kirari learned about and was intrigued by the use of everyday things in her project, noting "…lifesavers can be reused for tires of a vehicle… I never would have exposed her to those aspects of making with products." Tod also highlighted Eleanor's creative use of material in her prototype, specifically acknowledging the use of straws as a gutter system to collect water for animals. This too was highlighted in one of Eleanor's videos (see Figure 7).

Further, parents expressed how engaging in the program led to curiosities and questions about knowing how things worked, as well as provided opportunities for their child(ren) to "see engineering through the day-to-day stuff" (Tod). The following quote was made by Angela as she reflected upon Annie's change as an engineer through the program:

> I also think that it's also made her think about things more, like she asked me a million questions… So she's like, "Mom, why do you think that if there's water coming over a dam that… How would you like—you can't automatically just stop it…" You know like, you can just tell, she'll see something in the world, and then she's thinking about how it actually works and why it was created, which she didn't really do that before this.

Jake too described instances in which Beth pointed out engineering marvels while driving down the road. For instance, "Then when we go over the big bridge like we just saw this weekend, it's like, 'Hey, look, this is quite the civil marvel, how high we are over the river.'" As described by Rachel, she foresees such an inquisitive mindset and exploration of objects as leading to her daughters becoming and being engineers. "She [Joy] wants to know how it works. She's one that is willing to just pull things apart just to kinda see… And so, yeah, I definitely see them as an engineer."

Discussion

In this paper, we argued and illustrated how a program grounded in engaging children and their family members in engineering design processes in their home environments during the pandemic supported the development of children's engineering identity. The program was redesigned to address the constraints of the pandemic (e.g., social distancing, limited afterschool programs), while also drawing upon the role of the family and the home as a rich learning environment (e.g., Civil, 2016; Rodriguez et al., 2021). This included engineering kit exchanges at participant homes, virtual show-and-tells, and the utilization of interactive slides. As such, the results from this study add to our scant understanding of identity development in engineering, particularly the core elements of situational interest, recognition of self and others, self-efficacy, and "doing" engineering in a learning environment that is often considered a black-box, the home (Gitlin, 2003).

Children's interest was often framed as their favorite component within the process of engaging as an engineer (e.g., creating a prototype), as well as grounded within one of the engineering tasks facilitated through a kit. In relation to Hidi and Renniger's (2006) four-phase model of interest development, this program may have initiated children's interest in engineering (i.e., triggered situational interest) through a particular kit or process that persisted from the beginning to the end of the program (i.e., maintained situational interest); thus, informing their identity development as engineers (e.g., Godwin et al., 2016). Results from this exploratory study highlighted how some children developed an understanding of and interest in circuitry within the engineering design process. In addition, children expressed an interest in learning more about the different types of engineers, which supports research by Ozogul et al. (2017) that found a positive correlation between Grade K-5 students' interest in engineering and knowledge of what engineers do. We hypothesize this interest in engineers was likely sparked through the engineering passports and/or the kits themselves, which included information on different engineering fields relevant to the kit. And although children in this study expressed interest in engineering, this interest did not transform into an interest in being an engineer for all child participants (e.g., Wade-Jaimes et al., 2021), but was framed as utilizing engineering processes and practices in other parts of their future self, such as a hobby or part of another career. They were able to make an informed decision about their future self based on their engagement in the program.

Recognition has been shown to be one of the strongest constructs shaping an individual's identities in a STEM field (e.g., Hazari et al., 2010). In this study, the majority of children agreed that their family viewed them as being an engineer. As noted by Rodriguez et al. (2019), family could serve as one of the earliest sources of recognition. Likewise, parents in this study acknowledged the ways in which their child(ren) enacted actions and behaviors of engineers. We hypothesize that parents' perception of their child(ren) as engineers may have shaped children's recognition from others, particularly from members of their immediate family, thus supporting their engineering identity development. Further, children in this study recognized themselves as a particular type of engineer (e.g., biomedical engineer), which, based on their interview responses, was likely informed by their situational interest developed within the program. This implies that supporting situational interest in engineering at an early age may also influence the recognition of one's self as an engineer. This self-recognition is not consistent with undergraduate students or adults whose self-recognition as a STEM person was based on sense of belonging and/or an understanding of STEM concepts (Carlone & Johnson, 2007; Rodriguez et al., 2019).

Children's self-efficacy in this study can be described as a cyclical process in that as they gained an understanding of being an engineer through their interactions, actions, and behaviors (i.e., doing engineering), their beliefs in their ability to complete an engineering task shifted (i.e., self-efficacy). We contend that this has implications for the children's developing competence beliefs as engineers as Zabriskie et al. (2018) have documented how self-efficacy is a precursor of competence. Although competence alone is not enough to positively inform one's identity development as an engineer, the more an individual believes in their ability to understand STEM concepts, they are more likely to believe that others view them as a STEM person and the more interested they are in a particular STEM field (Cribbs et al., 2015; Godwin et al., 2016). In line with previous research by Sha and colleagues (2016), we argue that caregiver engagement and children's perception of adult support through this program remain a significant contributor to child self-efficacy development and their subsequent interest and identification in STEM and engineering.

Lastly, there were several ways in which children discursively enacted and behaved as engineers through the program, particularly through their engagement in the engineering design processes (Weick, 2004). Likewise, parents too expressed different ways in which they perceived their child(ren) doing engineering in their home environment. These were more aligned with Capobianco and colleagues' (2012) engineering attributions (e.g., being creative, designing things around us), as well as Jang's (2016) STEM competencies, than children often limited and/or misguided understanding of engineers as building or fixing things using tools such as blueprints and computers (e.g., Karatas et al., 2011). Doing engineering included experiences with collaboration, failure, iteration, and perseverance. As expressed in the interviews from this study, children's experiences with failure were described as an opportunity to learn which is more common to professionals across STEM fields and less common for children at this age (Simpson & Maltese, 2017; Simpson et al., 2019). In addition, doing engineering included resourcefulness as everyday objects and materials took on a new role through the program (Sheridan & Konopasky, 2016). We contend this was due to closures during the pandemic, as well as the uniqueness of the home environment in which they had more materials, objects, and tools at their disposal (e.g., fuzzy dice) than many other learning environments. Likewise, as described by parents, children began seeing the world and their surroundings differently, through the lens of an engineer. They began questioning how and why things worked. From our perspective, this represents an ontological shift; a transformational change in their participation and developing identity as a legitimate member within the field of engineering (Wenger, 1998).

Collectively, and as supported through identity research (e.g., Cribbs et al., 2015; Godwin, 2016), situational interest, recognition, self-efficacy, and doing engineering are shaping and informing children's developing identity as an engineer and identity trajectory as an engineer. Beth, for example, articulated an interest in the engineering design process and learning more about the field. Beth further provided examples of ways she enacted the actions and behaviors of engineers (i.e., doing engineering). Yet, Beth's self-efficacy and recognition from others as an engineer were expressed as "in the middle" and situated within experiences with and perceived expectations of others (e.g., father). This illustrates that while some of these components were more positively "audible" or salient than others (e.g., interest), such components will continue to change and take shape with additional engineering experiences within the larger learning ecology, including their home environment (Morris et al., 2019). Calabrese Barton and colleagues (2013) referred to this as identity work as traces of an engineering identity occur over time and within the norms and expectations of the learning environment and world they occupy.

We contend that the significance of this study lies in the potential to develop children's engineering identity in home environments beyond the pandemic. This learning environment is more easily accessible than other learning environments (e.g., museums, schools) that present barriers such as cost, cultural and structural inequalities, and high-stakes testing (Dawson, 2014; DeWitt & Archer, 2017; Hammack & Ivey, 2017). It is also possible that family members, similar to prospective and practicing teachers, do not possess an understanding of or portray common misconceptions about engineering (Martin et al., 2016; National Academy of Sciences et al., 2008). We believe that providing facilitation guides that included potential questions to pose or extra pictures on how a circuit worked, as well as modeling different instructional approaches through the show-and-tell meetings, created a structure for parents to support their child(ren) as engineers. Additionally, we acknowledge that the results from this study hold promise in terms of a diverse and inclusive engineering workforce as the development of one's identity is associated with one's possible self and career (e.g., Dou & Cian, 2021; Godwin et al., 2016; Verdín et al., 2018).

Lastly, while children in this study did not identify their parents as playing a role in their engineering identity development, research would suggest that their involvement and interactions with their child(ren) throughout the engineering design processes built into the program may be one of the most influential experiences on their early identity development (e.g., Dou & Cian, 2021; Dou et al., 2019; Rodriguez et al., 2019). This prior research highlighted the power of talking about STEM concepts at a young age on undergraduate students' identity in STEM as an adult. This was more prevalent than informal learning experiences such as participation in STEM clubs and camps (e.g., Dou et al., 2019). In this exploratory study, parents and their children talked about STEM concepts *through* an informal learning experience. As such, we have documented elsewhere the dynamic and multiple facilitation roles that parents enact to support their children through the engineering design process (Simpson et al., 2021). For example, as a social broker, parents mediated social transactions/interactions and the flow of information between people. As a second example role, parents were observed instructing their child on how to do something within the engineering design process (i.e., role of teacher).

Limitations and Future Research

One limitation of this study is the family participants as the pandemic presented challenges in terms of recruitment and seemed to target families that had access to the internet and other resources (e.g., soldering irons). At least one parent was more likely to work from their home and built the program into their schedules (i.e., structure). In addition, some parent participants had strong STEM career affiliations, including engineering. We acknowledge how this likely shaped the results of this study as research has documented the role of parents in making choices aligned with their careers and interests (e.g., Zammitti et al., 2020). Future research could also examine how well the program shapes children's engineering identity development and parents' perceptions of their child(ren) as engineers with a more diverse population of families. A second limitation of this study was the number of families as we were not able to consider similarities and/or differences in children's identity development through the lens of intersectionality (Cho et al., 2013) and/or cultural and historical inequities (Archer et al., 2012). Conducting a similar program and research study with a larger and more diverse participant population would increase our understanding of how children's engineering identity development is shaped and informed beyond situational interest, recognition, self-efficacy, and doing engineering. This could even extend the study of one's developing engineering identity to include additional intervening factors, both assets and hindrances, that were not accounted for in this study such as a growth mindset (e.g., Zanin et al., 2022).

Another limitation was the use of a single interview to consider the development of children's engineering identity as part of their identity trajectory. An ethnographic study with multiple data sources and data points would continue to build on the results of this exploratory study, while also providing a deeper understanding of the various factors influencing young children's engineering identity when actively participating in an engineering design process with their family. Lastly, there is limited research that examines identity development of children in one or more STEM fields through engagement with family members in their home environment or day-to-day activities and interactions (Simpson & Bouhafa, 2020). More research may provide the field with a better understanding of how family members support (or hinder) children's identity development as family members may not be considered an "expert" in STEM, but may be considered an expert in their children's abilities, experiences, prior knowledge, and dispositions (e.g., Umphress, 2016).

Conclusion

This exploratory study was designed to examine how children's engineering identity might develop through the co-creation of engineering concepts and engagement with engineering design thinking and processes in an out-of-school context, particularly the home environment. Using accessible and approachable methods such as age-appropriate engineering kits, as well as the intentional inclusion of family members, new insights and practices have emerged that have the potential to inform the identity development of children as engineers. Unprecedented constraints and barriers due to the COVID-19 pandemic were transformed, and ultimately leveraged, to facilitate place-based engagement with engineering practices in the unique contexts of participant homes. In this way, we contend that engineering concepts were made more tangible and relevant to children's lives, facilitated by new opportunities to engage with and learn alongside their parents in ways that they otherwise may not have. This study contributes unique insights into children's engineering identity development and provides a foundation for thinking about ways that families might be further incorporated into the learning and growth of their children as engineers. Further, exploring engineering identity development through engineering activities within familiar spaces such as the home extends the conversation around out-of-school environments and their benefit to children's learning and development.

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Appendix A

Semi-structured Interview Protocol for Child Participants

1. What was your favorite engineering design challenge? Why? (Probe into the design steps if not mentioned. For example, tell me more about the creation of the prototype.)
2. Do you have anything you want to show or share with me about any of the kits or your project?
3. I am going to read several statements. For each one, tell me whether you agree or disagree and why? (Probe for examples.)

   - I have good ideas in engineering design challenges.
   - I love designing and building prototypes.
   - I would often stop when something did not work well. (Probe: What were you feeling when you stopped? Why was this strategy helpful for you? What happened when you started working on your prototype again?)
   - I see myself as an engineer. (Probe: Is there a type of engineer you feel that you are more like? Or How would you describe an engineer?) What one word would you use to describe yourself as an engineer?
   - My family and I worked together on the different engineering design challenges.
   - My family sees me as an engineer.
   - I would like to learn more about engineering. Why or why not?
   - It is likely that engineering will be a part of my job someday. (Probe: How do you think being a part of this program informed your thinking about this?)
   - Being a part of this program was really cool.

4. Before we end, now is the time to tell me anything else you would like to share that we have not talked about yet?

Appendix B

Semi-structured Interview Protocol for Parent Participants

1. How would you define engineering within a home environment context? How might this be similar to and/or different from your views of engineering before the program?
2. What did you notice in terms of [child's name] development as an engineer in this program? How did it change from the beginning of the program? (Probe into different areas such as interest, competence, design thinking, agency, etc.).
3. What did you learn about your children through your joint engagement with the kits and the self-identified problem? (Probe for examples).
4. How did your interactions with [child(ren)'s name(s)] change? Why? How might this have impacted their development as an engineer? (Probe for examples.)
5. How do you think you might continue to use what you learned in this program?
6. Is there anything else that you can think of about the program or about what you've noticed about [child's name] development as an engineer that you would like to share?