ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #38229

Parental perspectives: Examining caregiver experiences and perceptions of growth and learning within an out-of-school elementary engineering program

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Abstract

Caregivers are critical to children's academic and social growth and development. As an adult who provides direct care and support, caregivers play a large role in what concepts and experiences children are exposed to, engage with, and pursue. A growing body of research has highlighted how caregiver influence manifests within out-of-school contexts, yet less is known about the impact of out-of-school learning and engagement from the perspectives of caregivers themselves. This study explored experiences and shifts in caregiver perceptions of shifts within themselves and their children through participation in an out-of-school home-based engineering program. Data were derived from post-program interviews with over 20 participating caregivers from three years of the program. Results illuminate various experiences and shifts in caregiver self-perception and understanding of their children's learning and development. Specifically, these shifts included enhanced self-reflection and introspection, positive shifts in caregiver interactions with children, and observed increases in self-efficacy and complex thinking within children. Findings contribute to a growing body of knowledge of family engagement and the distinct perspective that caregivers can provide on children's learning. Further, shifts in caregiver self-concept and self-efficacy in engaging in engineering content make a unique contribution and provide insights into ways that caregiver engagement in out-of-school learning might be adapted to incorporate more accessible learning opportunities, especially those that occur in the home.

Introduction

Previous research indicates that caregivers have a significant influence on the learning and development of their children, particularly in environments outside of school [1], [2]. Within STEM, purposeful interaction and dialogue between caregivers and children have been found to enhance curiosity and interest in STEM disciplines [3] and facilitate the exchange of information and knowledge through question-asking and relaying of experience [4]-[6]. Despite this critical role, particularly in out-of-school time (OST), we know relatively little about caregivers' experiences and ways they might perceive value and growth through participating in out-of-school STEM learning opportunities. Few studies have focused specifically on the perceptions of caregivers and shifts they see in both themselves and their children that may contribute to children's interest or self-efficacy in STEM. Because caregivers may act as supports or barriers to children's access to and engagement with out-of-school learning experiences, and the majority of caregiver and child time is spent in such contexts (e.g., the home), caregiver engagement can have consequences for children's STEM interest in and identification with STEM concepts and disciplines [7], [8]. As such, this study contributes to an enhanced understanding of the perspectives of caregivers who engage in out-of-school STEM learning opportunities, which is critical to the development and refinement of family engagement methods that contribute to the STEM interest trajectories of children. We specifically explored shifts in caregiver perceptions through participation with their children in an out-of-school home-based engineering program and sought to answer the following research questions, 1)

What changes did caregivers see in themselves through participating in an engineering program in their home? and 2) *What changes did caregivers see in their child(ren) through participation in an engineering program in their home?*

Relevant Literature

This study is supported by two bodies of literature. The first is focused on the role and benefits derived from learning in out-of-school contexts and how such environments can uniquely impact children's engagement and identification with STEM concepts and disciplines. Much of the scholarship in this area centers around informal learning experiences and programs (e.g., [9], [10]), with less attention paid to how OST STEM learning might manifest and impact children in the home environment. Even fewer studies focus on engineering in out-of-school contexts, which may be exacerbated by persistent challenges to incorporating engineering design practices and thinking within earlier stages of learning [11]. The second is focused on the unique role that caregivers play in the learning and development of children. Caregivers' understanding of STEM concepts, perceptions of their children's STEM abilities, as well as their attitude and behavior toward STEM in general, can all impact a child's engagement and interest in STEM [12].

Out-of-School (OST) STEM Activity

While a great deal of research has focused on school-based parental involvement in STEM learning, other research suggests that parents are more involved in out-of-school time or home-based STEM activities [1]. Due to the wide array of OST and free-choice activities that are available to children and their families, the majority of science learning occurs outside of school [13]. Engaging in these free-choice, informal STEM-related activities during childhood has been found to significantly contribute to adults' STEM interest and career choices [13]-[15]. Out-of-school time STEM activities tend to be more informal in nature, often reinforcing activities in which children already are involved (e.g., school, sports). Compared to school-based activities, out-of-school time STEM may be more beneficial to youths' development of STEM self-efficacy given the low-stakes and flexible nature that allow youth to explore and gain confidence in STEM [1]. Further, there is growing evidence supporting the impact that out-of-school, informal learning, and engagement with STEM concepts can have on children's investment and interest in STEM disciplines and careers [16]. However, despite the significant amount of time spent in the home environment, there remains a dearth of research specifically investigating the nature and impact that home-based, out-of-school learning may have on the learning supports for and engagement with STEM disciplines [17].

Compared to curriculum-focused approaches typical of formal STEM education, home-based STEM learning embraces families' own cultures and lived experiences (i.e., funds of knowledge) [18]. Caregivers often bring their own prior knowledge and skills that represent a family's inner culture and experience into learning and engaging with math problems [19], engineering practices [20], and science concepts [21]. Further, familial support and effort to provide opportunities for their children to engage in STEM-related activities have also been identified as an effective means to decrease gender disparities in STEM interest [22] and contribute to children's science identity development [23] among low-income and minority families. Yet,

informal STEM experiences tend to be predominantly program-based (e.g., after-school clubs, competitions) or within community organizations (e.g., museums, science centers), with less known about at-home experiences despite the home being where children and families spend the majority of their time [24].

Caregivers Perceptions of STEM

While involvement with school-based activities and homework typically comes to mind when we think of caregiver involvement, this participation also occurs in more informal ways, including engaging in everyday STEM-related activities [25], visiting and participating in science museum programming [26], participating in OST math, science, and computer activities [3], or talking about science [27]. All of these forms of caregiver engagement can influence children's values, beliefs, choices, and achievement in STEM.

Caregiver beliefs about their knowledge of and ability to help their child with STEM influence their involvement in STEM activities with their children [28]. While caregivers believe they play a large role in inspiring their child's interest in STEM, most are not confident in doing so, such that only a small percentage actually engage in STEM activities with their children [25]. Caregivers' lack of confidence in their own abilities and in supporting their child in STEM often leads to decreased involvement in STEM activities with their child [12], [29]. In fact, caregivers may actively avoid engaging in STEM activities with their children if they perceive themselves as lacking appropriate knowledge or experience [28]. When they do engage in STEM with their children, caregivers often struggle with how to teach or support their children due to perceived gaps in their own knowledge or abilities [25]. When helping their child with homework, caregivers often do not emphasize the importance or relevance of the STEM content (e.g., math, science). However, a growing number of intervention programs have begun to help caregivers learn how to convey the importance of STEM to their children, often focusing on the relevance or importance (i.e., utility value) [12]. These programs have been found to positively influence children's perceptions of the value of STEM [30].

Caregiver beliefs and expectations about their child's abilities and achievement in STEM influence their children's own views of their abilities and expectations of success in STEM [31]. However, caregiver beliefs sometimes do not reflect their child's actual abilities but rather are based upon characteristics of their child (e.g., gender), context, and general beliefs and values held by the caregiver [12]. A large amount of attention and research has focused on gender-based beliefs. For example, many caregivers hold implicit gender stereotypes, such that they perceive boys to be better at and more interested in STEM with the reverse pattern holding true for girls in English [32], [33]. These gendered beliefs influence caregiver behaviors (e.g., encouragement and support of whether or not to pursue STEM subjects and careers) and children's self-perceptions of their own abilities in STEM [12].

Previous research notes that caregivers are more likely to talk about and provide activities for their children that they value or feel capable of supporting [34]. For example, caregivers who value/have a positive attitude towards STEM may be more likely to help children with their STEM homework or take them to visit museums [12]. Caregivers' beliefs and value in STEM

might be demonstrated through tangible actions, such as actively providing STEM resources and opportunities or directly encouraging or engaging in STEM-related activity with their children. However, subtle demonstrations of the importance or value a caregiver holds in STEM can also be communicated by reading STEM-focused books and articles or watching STEM-related television shows [1], [12], [33], [35].

Findings on the mediating role of caregiver actions on the relationship between caregiver and child beliefs and values in STEM are mixed. As such, more work is needed to examine the beliefs and perspectives of caregivers, and how through their own experiences engaging in STEM activity with their children, caregiver values might be transferred and internalized by children. For example, parental involvement in school- and home-based STEM activities, provision of encouragement and support of children's autonomy and agency in STEM, and communication patterns during co-activity in STEM may be important in children's socialization related to STEM [12].

Theoretical Grounding

Families and home environments represent critical social contexts for child development and caregivers are considered essential partners with teachers in children's education [36]. Learning that occurs independently of experts such as certified teachers is beneficial to educational development because it provides personalized experiences and emotional support that often cannot occur in classrooms [37]. The overarching goal of this research project was to engage families in opportunities to explore STEM concepts and skills and expand access to STEM learning and activities into home environments. Bell et al. [38] defined learning as "a joint collaborative effort within an intergenerational group of children and significant adults" (p. 33). Because they have more knowledge and experience, caregivers can enact various roles to support their children in learning and transmit values and expectations around learning and problem solving [39]. However, children are not considered passive learners in this study, but rather they share ownership in learning throughout their engagement with the engineering design cycle. Eccles' Model of Parent Socialization [40], [41] and Rogoff's Theory of Guided Participation [42] inform our investigation and center the values and expectations that arise within and between caregivers and children.

Many factors influence caregivers' choice to be involved in their child's STEM learning and how that involvement influences STEM-related outcomes. In this study, we draw upon the work of Eccles and colleagues, namely expectancy value theory (EVT) and the model of parent socialization [40], [41], [43], [44], to better understand ways that caregiver values, beliefs, and socialization impact their child's informal STEM learning and experiences. The EVT framework can explain STEM interest and achievement across ages, from preschool through postsecondary contexts [45], [46]. The EVT framework describes ecological, psychological, and sociocultural influences on STEM activity choices and performance. Children are more likely to participate in an activity when it is valued or when they have high expectations of success in the activity. A variety of ecological factors influence these expectations and beliefs, including personal and cultural characteristics, environment or context, previous achievement, and beliefs and behaviors of socializers, including caregivers, in a child's life. The model of parental socialization

represents an expansion of this socialization process [41] and posits that parental beliefs and perceptions influence their subsequent actions and behaviors. These actions and behaviors include conversations and provision of activities and support, all of which shape children's values, motivations, and choices [12], [31]. In their role as socializers, caregivers serve as "interpreters of reality" and "providers of experiences" for their children [12], [33]. Parents' interpretation of reality (i.e., shifts they perceive in themselves and their children) becomes apparent via their perceptions and beliefs about their child and STEM activities. In turn, these beliefs and values determine the opportunities that parents provide to their children, including the specific actions, behaviors, and engaging in STEM activities with their children [35]. These behaviors may serve as a mediating link between parent and child STEM beliefs and values [12].

Methods

This exploratory study aims to investigate the involvement and perceptions of caregivers who participated with their children in a STEM engineering program in their homes or out-of-school contexts. Using a descriptive qualitative method and thematic analysis, interview data were analyzed via a process of reducing information into significant statements or quotes and combining those into emerging themes [47]. The inclusion of caregiver perspectives from 23 families provides diverse data for the interpretation of narrow units of analysis (i.e., statements, phrases) and aggregation into broader units (i.e., themes, meanings) [48].

Context

This study is part of a larger grant project working in partnership with families and community members to develop, implement, and refine an out-of-school elementary engineering program. A goal of this project is to uncover what roles and methods parents, mentors, caregivers, and other community members might employ to motivate students to become aware of, interested in, and prepared for a career as an engineer. One of the aims of this larger project is to examine shifts in caregiver views of engineering, ways to support their child in engineering design practices, and their beliefs that engineering is a viable option for their child to consider as a degree and career. To meet this aim, the current study explored the perceptions of caregivers who participated in the first three years of an engineering program within out-of-school contexts. Families were recruited for participation through informational fliers, social media posts, and partnerships with local community organizations (e.g., Boys & Girls Clubs, local schools, public libraries). Programs occurred between January and June of each year (2019-2021). While aspects of the program evolved to meet the specific needs and circumstances of participating families, the general program, materials, and project formats remained consistent each year.

Participating families engaged in two elements of an at-home engineering program. The first involved use of researcher-developed take-home engineering kits. These kits consisted of two guides – child-oriented instructions and an adult facilitation guide – as well as basic materials and equipment (e.g., popsicle sticks, small motors, hot glue guns, etc.). Each kit was designed to expose families to the complete engineering design cycle, starting with problem identification, brainstorming/solution ideation, prototyping, testing, redesigning, and communicating results. The second element involved applying the engineering design cycle learned via the take-home

kits to engage in the self-identification of an engineering problem or challenge in their home or community, the ideation of an engineering solution, and engaging in designing, prototyping, and testing their proposed solutions. Building from the exposure and practice provided through the take-home kits, caregivers and children worked together to implement the engineering design cycle using readily-found recyclable materials from around their homes or community.

Participants

Participants in this study are 23 caregivers from families who lived in either a mid-sized city in the Midwest US (Years 1-2) or a small city in the Northeast US (Years 2-3). Participants and their families were racially and socioeconomically diverse, with caregivers self-identifying as Asian (7), Black (5), White (8), and multi-racial (3) and with incomes ranging from less than $25,000/year to more than $75,000/year. 10 participating caregivers had professional experience with STEM or currently worked within a STEM discipline (e.g., engineering or mathematics Ph.D.; software engineer; systems engineer). The remaining 13 caregivers self-described little to no experience with STEM. Familial and individual pseudonyms have been utilized when presenting the results of the study.

Data Source

The data utilized in this study are post-program interviews with the primary participating caregiver in the program. Interviews were conducted by researchers located at each research site and conducted via phone or virtually using Zoom and ranged from 30 to 90 minutes in length. Interviews consisted of open-ended questions posed to the caregiver, followed by occasional impromptu probing questions seeking clarification or further detail. Examples of interview questions include '*In what ways did you see your child grow through engaging in this program?*', '*How do you feel your interactions with your child around engineering changed, if at all?*', '*How did you grow through engaging in this program?*', and '*How do you feel your interactions with each other around engineering changed, if at all?*' All interviews were recorded via phone, voice recorder, or the Zoom recording feature. Interview transcription was conducted using available software (e.g., Scribbie, Ottr.ai) and services at each research site. Transcriptions were reviewed and cleaned by researchers to ensure accuracy and completion.

Data Analysis

Qualitative thematic analysis was conducted beginning with examining phrases and sentences that applied to study research questions from interviews transcribed verbatim. Significant statements and perspectives were grouped into broader themes or units of information to provide a foundation for interpretation [47]. In this case, themes refer to specific patterns of meaning or constructs and are drawn from directly observable, caregiver perspectives and dialogue [49]. From these themes, textural and structural descriptions of changes caregivers perceived in themselves and their children were developed to illuminate 'what' they experienced and 'how' those experiences occurred. Researchers then engaged in a synthesized, aggregate discussion about and description of the essence of participants' experiences in order to draw conclusions and generalize across our sample where possible [50].

Results

Study results indicate several themes amongst caregivers and the changes they saw both within themselves and within their children through participation in the out-of-school STEM engineering program. We present the three most prominent themes and provide examples from several participating families that demonstrate and support what shifts occurred within caregivers. We begin with two themes indicative of shifts caregivers saw within themselves – their self-perception of ability and perceptions of their interactions with their children. We end with a third theme focused on shifts caregivers observed in their perception of their children.

Caregiver Reflection and Changed Self-Perceptions

A primary theme that emerged amongst participating caregivers was a recognition of an increase in self-reflection and introspection regarding their engagement and interactions with their children. Several caregivers noted how this reflection contributed to a reorientation process in which caregivers began to understand the way that they learn unknown or complex content differently. Through this self-reflection process, some caregivers also recognized their own biases or aversions to learning certain concepts or content.

One example of this comes from caregiver Tonya who participated in the first year of the program with her daughter, Cindy. This dyad worked closely together in the development of a delivery robot that could move across various terrain in their home. While occasionally aided by researchers and volunteer engineers, this pair often worked independently using materials, tools, skills, and information provided through the program. In doing this, Tonya noted that working with her daughter in this way highlighted her own deficit approach to learning certain content. She noted,

> *But when it came to the engineering and the programming aspect of it, seeing your [Cindy] ability to remember the code, and remember the passwords, and your comfort with the technology was something I hadn't seen before. So that was pretty amazing to me. Yeah. It also made me realize, again, my own personal general discomfort with learning new technology. So, I have a bias and it helped me learn that bias.*

Another participating caregiver, Uri, described her reflections on how this out-of-school program fostered a different perspective on her self-efficacy, as well as her children's thought processes. She said,

> *I didn't know that I could build a design thing. Art was never my thing, nor science, I write and I teach, so this was beyond me. It's for those folks, not me, but having to do it as a family it brought me closer to Zach, and to his mind, and to his world. I was able to see how Chari could have a future in the field as well, so I think it is important for families to participate because it really knits the family closer together.*

In working closely with her children around unfamiliar content, Uri found that she emerged feeling more confident in her abilities and in working with new and different materials, stating,

> *You see construction people work with things and I was intimidated by all the little tools that you had out, all the art materials, and seeing that little sewing machine and all those things and actually using it and overcoming my fears, it really helped because somewhere else I might not have tried. I might've just stayed in the background and not participated at all, but it was a welcoming environment, so it made it easier for someone like me who's not... I'm tech savvy when it comes to computers, but anything else I'm not, so it made me like, okay, I can do this.*

Yet another caregiver who had extensive background and training in engineering noted shifts in his self-perception, as well. Mark participated with his daughters Jenny and Georgia. As an engineer, Mark approached this program and task differently than other caregivers. Yet, he noted that this program, it's context, and working specifically with his children prompted him to think about his approach to engineering content and his own understanding. Mark said,

> *... as you mentioned, it's my background. I don't think about it a lot when I'm trying to solve a problem, I'm trying to do anything. It's something by nature. I don't think about the steps but with this age group, I'm trying to explain everything and sometimes I feel that, maybe I understand that details more because I looked into the details. So I'm trying to explain everything in detail and I forgot after I finish that some points that I was missing without fully understand maybe. And now I understand it because I'm trying to explain it to this age.*

<u>Caregiver-Child Interaction Shifts</u>

A second theme related to personal shifts within caregivers centered around the nature of the interaction between themselves and their children. Many caregivers noted their purposeful positioning of children as equals or partners in solving problems or challenges together. One participating dyad from year two of the program made note of this shift. Through participation in the program, Karen found that her interactions with her son Roberto, as well as her expectations of success in this work, shifted. Karen said,

> *...as the sessions went by, I felt more comfortable with my interactions with Roberto, but sometimes I felt that I was calling his attention on it, that sometimes I felt like I was doing the project for him. So, I was like, 'You need to talk to me more, and not be so distracted, worrying about what the other kids are doing' ...He wanted to compare his project to other people. I'm like, 'It doesn't matter. We're not here to compare. It doesn't matter if ours is best or worst. We just have to try to get it done the best way that we can.' And so, I relaxed more, but I also caught myself policing him or calling him to focus more and to not leave the task just for me, that it was a group task. It was a partnership that we had to work together.*

Another caregiver noted the same perceived shifts in interacting with their child as a collaborator or a project partner. Jennifer and her son Billy worked together on several engineering kits at home, and Jennifer observed that her engagement tactics with Billy shifted and she was challenged by the changing dynamic that came from learning together. She said,

> *I know he's focused, I don't want to take him off of his focus, but I'll try to maybe ask the question in another way or wait a minute or two. Sometimes I think one of the things, the difference between being a partner in these projects versus being a teacher, like if that was a teacher I would have a way of how I would present it right off the bat in more of the concept.*

Jennifer noted how her interactions were impacted by the shift in power dynamics that came from learning together, as well. This was alluded to in discussion around their work process. Jennifer stated, "*But I felt like we were both learning about what the project was at the same time. So that made it a little more challenging because he would get to a different step and I'd be somewhere else and so that was challenging sometimes, I guess, collaborating in that way."*

Observing Changes in Child Thinking

Shifts that caregivers observed in their children emerged as prominent aspects of program participation. Several caregivers noted that their perception of their children's understanding and engagement with engineering concepts also changed and evolved. Some caregivers observed shifts in child thought processes, too, which they believed influenced other positive learning outcomes and behavior such as how their children see the world around them and increased inquisitiveness.

A participating caregiver from year three of the program, Angela, observed such shifts in her daughter Annie. She noted,

> *…she was much more systematic and thinking about it, and she was like, "Well, if I did this... " And then she lay it out, and then she was like, "No, but I don't know if you tried this... " I could just tell her thought process was more in-depth, I think, and I also think that it's also made her think about things more, like she asked me a million questions…*"

This same caregiver also observed subtle shifts in her daughter and noticed that Annie was looking at her surroundings and community differently. She observed, "*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.*"

Caregiver Amanda saw similar changes in perspective within her son, Eden. She observed that new opportunities afforded to them through participation in the program provided a chance to build confidence in engaging with others. She said,

> *…it was nice to hear Eden's confidence in talking with you. I felt like that was an improvement. And he said before our presentations this morning, that he's never given a*

> *presentation to anyone before. And so it was fun to see him get a little bit more comfortable, a little bit more confident in exploring those ideas and being that person…but yeah. I watched the dynamic change throughout.*

Caregivers also perceived enhanced creative, independent thinking in their children, as well as the development of growth mindsets or more positive approaches to challenges. Year one participant Uri found this to be the case in her children Zach and Chari. She noted,

> *…I just saw in both of them a new love for science and engineering. Zach always loved science, but for Chari to really fall in love with something that she always felt elusive and always felt that she could never be a part of, kind of like, that's Zach's thing and not my thing, that as a mom was really good to see. And for Zach, like she said, the completion of a project, but also to see the thought process, what he underwent throughout the entire program. Usually he can think of something and he can do it, like Legos, you buy the box and put it together, or a kit. But this he had to actually think about it, design it, write it out, get the parts, put it together. It was challenging, but he did it with grace, and he learned patience.*

This same sentiment was described by Karen in reference to her son, Roberto. Karen said, *"I did see him change. I saw him think more critically about problems. Also, I got a chance to see how he thinks through different problems and different problems of the different activities. He didn't think the same."*

Jennifer, too, observed this same occurrence taking place in Billy. She said,

> *It [the program] pushes him to think more, beyond what they're expected maybe in school, you know? It pushes him to think more, but how are you going to do this? And why? And how would you sell this? Like the tennis shoe. Or he asks more critical questions, so that's something I really like about the project. It kind of elevates their thinking, and it makes them think out of the box a little bit more… it pushes the kids a little further than it would at school.*

Discussion

Despite a growing body of knowledge around caregiver impact [1], [2] few studies have specifically examined the experience of caregivers and their perspectives and growth through engagement in out-of-school learning opportunities with their children. As such, the purpose of this exploratory study is to highlight and better understand the specific experiences of caregivers and shifts in their perceptions within an out-of-school context. Specifically, we sought to answer the following research questions, 1) *What changes did caregivers see in themselves through participating in an engineering program in their home?* and 2) *What changes did caregivers see in their child(ren) through participation in an engineering program in their home?* The current thematic analysis of transcribed interviews revealed distinct patterns and ways in which caregivers changed and developed, as well as changes they observed within their children.

Through their participation, caregivers came to recognize certain shifts in their children's perspectives and thought processes which they found to be beneficial and positive. Of note, caregivers also observed, or felt, shifts and changes within themselves. These findings hold relevance and support foundational aspects of Eccles' [40] expectancy value theoretical framework which views STEM activity choices and performance as ecological in nature with symbiotic social relationships impacting interest and forms of engagement. Through participating in the program as partners or project collaborators, caregivers were afforded opportunities to see and reflect on their interactions with their children. In doing this, caregivers noted their growing understanding of how they absorb and translate technical and complex information (i.e., engineering concepts). This was concurrent with caregivers' enhanced awareness of how their children understood and applied such information. In this way, caregivers became active socializers and demonstrated a growing awareness of the ways that their own beliefs and expectations influenced the experience and understanding transferred to their children, through their involvement [12]. We identified three primary themes in relation to the unique perspectives of caregivers participating in the program. Each theme was observed across nearly all caregivers in the study and was uniformly positive in nature. That is, from the caregiver's perspective, the nature of the shifts they observed in themselves and in their children were understood to be socially, emotionally, and developmentally beneficial.

Collectively, the results of this study indicate benefits to the social-emotional health and development of both caregivers and children. In their descriptions of their personal experiences in the program, caregivers noted becoming aware of their own biases and perceived deficits in engaging with and learning STEM concepts, new technology, or engineering processes. The opportunity to engage in a learning activity in an approachable, out-of-school context afforded caregivers the chance to reflect on their own learning and development with engineering design in tandem with that of their children. Caregiver thought processes and implicit feelings toward engineering were illuminated, spurring deeper thinking around how this might come across to their children. Thomas et al. [28] noted that preconceived notions about one's own ability with challenging concepts or STEM constructs may deter participation in STEM programming. However, our findings indicate that through participation in a collaborative, home-based engineering learning program, some of these perceptions or psychological barriers may be diminished. In this way, caregivers' perception of their own lack of engineering knowledge is made less influential [25] and they are more apt to join in. Further, some caregivers noted enhanced familial bonding and feelings of closeness through participation in the program. As noted by Jodl and colleagues [35], caregivers' perceptions of their own experiences and environments manifest and influence how they perceive their children and what they believe about their children's abilities with certain concepts, such as STEM disciplines. These same beliefs then influence how caregivers act as socializers to STEM by influencing the type of activities they facilitate or engage in with their children [35]. Findings from our study demonstrate this concept in real-time, as the opportunity to work and problem-solve together was described by caregivers as contributing to greater connectedness and awareness of how their children think, learn, and operate. While not an intended outcome of our program, such social-emotional benefits are noteworthy as they indicate a further benefit to engaging in out-of-school STEM activities, specifically with caregivers as collaborators and socializers [33]. These results tell us that the environment and opportunity to engage with children in this manner

can contribute to caregivers' greater understanding of their children's thinking. Subsequently, this shifts caregiver perception of their interactions with their children, particularly around engineering concepts or processes.

Results also support previous scholarship noting the benefit derived from out-of-school learning and environments. Within familiar home contexts and through intimate personal connections between caregiver and child, caregivers observed their children thinking more creatively and expressing greater and more comfortable exploration of ideas [15]. As a result of these observations, caregivers found that their interactions with their children during challenging or unfamiliar STEM projects were also changed. Many caregivers observed that the engineering tasks and projects provided structure for children to hold equal status in brainstorming ideas, testing materials, and making decisions. This not only provided an opportunity for caregivers to reframe their perspectives of their children as thinkers and doers [41], but it also provided the space for caregivers to observe children as equal contributors, or perhaps even an expert. Study findings around shifts in caregiver-child interactions demonstrate a unique glimpse into how out-of-school STEM learning programs and home-based project work might contribute to a "leveling of the playing field" or breaking down of traditional parent-child power dynamics. This has the potential to influence children's interest and identification with STEM [1]. Our findings support arguments for participation in such programs and their ability to contribute to greater self-efficacy and empowerment in children by providing a structured space in which they can make decisions and be positioned as equal contributors [1]. This has the potential to solidify such STEM engineering experiences in their minds as ones in which they are enabled and supported to think, lead, and act independently or as a true peer to adults.

Shifts in children's self-efficacy and learning impacted caregiver perspectives of how their children think and move through the world. Working through the engineering design in familiar out-of-school environments, children were seen shifting their thought processes and thinking in everyday life. Caregivers saw children employ the same methods of questioning and brainstorming solutions to problems they encountered in their everyday lives. As identified by Seker & Alisinanoglu [31], caregiver beliefs and expectations in their children's abilities subsequently influence their children's own beliefs and levels of self-efficacy. Findings from this study indicated that through collaborative activity and facilitated, at-home engineering programs, caregivers' perspectives and understanding of their children and their abilities evolved. Further, many parents noted that their children demonstrated more inquisitiveness and eagerness to understand how things work in their day-to-day environments. Likely stemming from the immediate applicability of the STEM engineering design cycle learned through take-home kits and self-identified engineering projects, children began to look beyond their immediate home environments and sought information about larger and more complex machinery or issues. This lends support for conducting informal, approachable STEM engineering programs in the home [24]. This shift in child thinking and perception extended beyond simple heightened curiosity around engineering design. Several caregivers also observed their children's increased comfort in asking questions, discussing ideas, and expressing creative, independent thinking. Perhaps inspired by the structured nature of the take-home kits and independent engineering challenges, children were observed feeling increased comfort with engineering as a discipline and with various concepts and design processes. Subsequently, this shaped their ability to engage in

conversation around these experiences. Such caregiver observations extend the argument for engaging in free-choice, out-of-school STEM-related activities during childhood and their benefit to child interest in STEM activities, as well as the development of skills and abilities applicable to any discipline or career choice [13], [14].

Recent research illuminates the benefit that caregiver engagement has on children's learning and development, as well as how out-of-school contexts play a critical role [1]-[3]. This study contributes to the STEM OST learning and caregiver engagement literature by centering the voices and perspectives of the caregivers who engaged in STEM engineering programming and design challenges with their children, in out-of-school environments (i.e., community organizations, the home). Parents may need support in recognizing what activities "count" as STEM but also in how to support and encourage their children in these activities [25]. Through engaging with accessible, scaffolded engineering design learning in out-of-school contexts, caregivers are afforded an opportunity to interact with engineering practices alongside their children in new and enlightening ways. Shifts that caregivers observe within themselves, their interactions with their children, and in the thinking of their children, shed light on the various ways this type of collaborative OST learning activity can benefit both parents and children. Simultaneously, this experience afforded families a more approachable opportunity to learn about, engage with, and apply engineering design principles in their everyday environments. Out-of-school, home-based interventions such as this can help parents improve their content knowledge and better support their children's learning [51].

Limitations exist within this study, yet they raise questions and offer directions that future research might take. While this study was exploratory in nature and was fortunate to be able to draw from three years of program data and over 20 participating caregiver perspectives, the post-program reflections represent a snapshot in time at the program's end. It would be useful and enlightening to explore how observed caregivers' shifts are sustained over time and what elements of the STEM engineering process "stick" and what does not. Taking a more longitudinal approach to the benefits children and families might receive through participating in OST STEM programs and activities may hold unique implications for child engagement and interest in STEM disciplines and careers. It would also be of interest to examine and better understand any potential gender differences that may manifest through participation in this form of OST STEM learning opportunity. To provide a contribution to persistent gender disparities in STEM disciplines and engineering, in particular, investigating what changes are occurring (or not) in boys and girls in collaboration with their caregivers may provide insight into how to better situate children to equitably benefit and apply STEM concepts.

Conclusion and Implications for Practice

Acknowledging caregivers' critical roles in children's STEM learning, we explored caregivers' perceptions and shifts they see in themselves and their children after participating in an engineering-oriented STEM program in out-of-school contexts. Our study highlighted three prominent themes regarding caregivers' perceptions and shifts through a descriptive qualitative and thematic analysis:

1. Caregivers reflected on their understanding of how they absorb and translate technical and complex information;
2. Caregivers noted that they position children as equals or partners in solving problems or challenges together; and,
3. Caregivers observed shifts in child thinking that resulted in positive learning outcomes and behavior.

Our exploratory study demonstrated that a program that purposefully positioned caregivers and children as partners or collaborators positively impacted caregivers' self-perception and understanding of their children's learning and development.

Furthermore, practitioners who are willing to engage caregivers in engineering activities in out-of-school contexts could be informed through our study about designing a more inclusive environment for both caregivers and children. Purposefully positioning caregivers as partners or collaborators lowers the barriers for caregivers who are not confident in STEM practices and allows caregivers with advanced prior knowledge to unfold their thinking. Prior studies showed purposeful interaction and dialogue between caregivers and children could enhance curiosity and interest in STEM disciplines [3]. Our study further demonstrated that interacting with children as a partner or collaborator is one effective way for caregivers to enculture children into STEM discourses that represent the various values and beliefs of a family.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. 1759314 (Binghamton University) and Grant No. 1759259 (Indiana University). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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