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Insights from Engineering a Community-Family Partnership Project

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Insights from Engineering a Community-Family Partnership Project

Abstract

The objective of this three-year National Science Foundation's Innovative Technology Experiences for Students and Teachers (NSF-ITEST) project is to develop, implement, and refine a program for integrating engineering design practices with an emphasis on emerging technologies (i.e., making, DIY electronics) into home environments of families with a child in grade 3-6 from under-resourced communities. This project has two components. Each family (1) defines a home- or community-based problem and creates a prototype to improve the lives of self or others; and (2) engages in low-cost engineering design kits in their home environments. This paper presents findings from two years of interview data, as well video data collected in project sessions and home environments from 21 families. Results are presented as highlights of finding from on-going analyses to address three research aims.

Background

In recent years, there has been an emphasis placed on inclusion of engineering design practices and engineering curriculum within K-12 schooling [1], [2]. In a recent report, the National Survey of Science & Mathematics Education (NSSME; [3]) found that approximately 3 percent of current elementary teachers have taken a course in engineering. This percentage increases minimally for middle and high school teachers, 10% and 13% respectively. Additionally, only 17 percent of elementary teachers felt prepared to teach engineering and 26% feel prepared to encourage students' interest in science and/or engineering. There is also a lack of professional development focused on opportunities to engage in science investigations/ engineering design challenges for elementary teachers as 38% of those surveyed as part of the NSSME study reported attending 15 hours or less of mathematics professional development in the last three years. Moreover, engineering curricula may be limited to students who have strong academic backgrounds, such as the top 80% [4]. This information highlights the scarce opportunities for youth to learn about engineering design practices in formal settings.

There are also opportunities for youth to engage as engineers in afterschool programs and summer camps [5]. As research suggests, engineering curricula and afterschool programs afford youth opportunities for learning STEM content, problem solving skills, and the ability to communicate ideas and results [4]. However, afterschool programs are typically short-term (e.g., two weeks, three months). We argue there is a critical need to include caregivers (i.e., any and all adults who consistently provide care and informal education to youth) and other family members (i.e., any individual who consistently lives with a youth at home) as stakeholders in meeting this demand through implementation of engineering design practices in the home environment. Previous research suggests that interest and engagement in STEM can be triggered at a young age, and caregivers are considered to be one of the most significant influences in this development [6], [7]. Additionally, family socioeconomic status and caregiver occupation may influence a child's decision to pursue (or not) a STEM major and occupation [8]. Our objective in this project was to develop, implement, and refine a program for integrating engineering design practices with an emphasis on emerging technologies (i.e., making, DIY electronics) into home environments of families with children in grades 3-6 from under-resourced communities. The inclusion of *making* within the program was also intentional as scholarship suggests that youth develop 21st century skills [9], [10] persist through failures [11], foster positive self-concepts and self-images [12], [13], and build positive attitudes towards STEM fields [14].

Research aims

The Engineering a Community-Family Partnership Project has three research aims. The first was to investigate features of the program that best support participation and implementation of engineering design practices among caregivers and children in their homes. Caregiver home involvement in education is associated with positive benefits for children [15], [16]. Yet, in general, adults' views of engineers and what they do are limited [17], [18]. This limitation suggests there is a lack of any or accurate engineering design practices employed in learning and play in most home environments. The objective of this aim was to develop a research-based community program to support families in implementing engineering design practices in their home environments

The second research aim was to investigate changes in children's engineering identity through engaging in engineering design practices with caregivers. As argued by [19], it is not uncommon for children to value the scientific enterprise, but not identify themselves as a legitimate participant within the sciences. We contend this is an issue across STEM more broadly. We agree with Tucker Raymond et al. [20] that by "understanding identity and identity formation, we can come closer to understanding why people make the life-path choices that they do…" (p. 559). The objective of this aim was to examine shifts in children's engineering identity by engaging in the engineering design process.

The third aim was to examine shifts in caregivers' views of engineering and ways to support their child in engineering design practices. As research suggests, caregiver beliefs and involvement with particular disciplines directly and indirectly affect children's perceptions and involvement with particular activities and disciplines, as well as influence children's future career choice [21], [22]. For example, [23] concluded that the amount of time a parent spent modeling a particular behavior predicted their child's involvement in a similar behavior two years later. This is an issue when adults' views of engineering are not well informed [17],[18], and likely non-existent in many home environments. The objective of this aim was to investigate how providing opportunities and support to caregivers can change their views of engineering and the support they provide their children in regards to engineering in the home.

Program description

The program was composed of two components and took place at a community-center over a five-month period. One, each family identified a problem in their home, school, or community that they could engineer a solution. This was a unique component to the program as the problem was personal and allowed families to utilize their experiences and knowledge relevant to the problem. In-person and at-home sessions supported families in the engineering design process from the ideation of the problem to the prototype to communication and demonstration of the prototype. For example, Walt (child) and Mac (caregiver) created two cat collar “alarms” to prevent one cat, Figaro, from blocking access to the litter box and food and water supply from the other cat, Sam. As another example, Gemma (child) and Tammy (caregiver) developed a folding tray for the front of Tammy’s wheelchair. This tray would allow Tammy to carry items such as her phone and a drink. Local engineering and makers were also invited to these sessions to support caregiver-child dyads as they had an expertise relevant to the projects.

The second component of the program was engineering kits that families were asked to complete at home between in-person workshops. Each kit was framed around an engineering task or challenge. For example, one task was stated as the following.

> You have been asked by a toy refurbish shop to brainstorm ways to give old toys a second life using electronic parts. Make a prototype that renovates, redesigns, and/or remixes an old toy. The prototype should change the look and feel of the toy, or the toy’s role in our life, using new materials.

The kits also included all required materials and tools, open-ended questions, images of examples, and career awareness information. Families were guided through an engineering design process – research, plan, create, test, improve, and communicate.

Participants

The first year of the project included three families and the second year of the project included 18 families. These families lived in the Midwest and Northeast regions of the United States. Across the two years, there were 16 female and 14 male child participants between 6-12 years of age and 14 female and 10 male caregiver participants. The self-identified ethnicity of the child participants included 36.7% African American, 13.3% Asian, 36.7% Caucasian, and 13.3% self-identified as “other” or two or more ethnicities. Caregiver’s educational backgrounds ranged from a high school degree to a doctoral degree and approximately 30% of the caregivers having a career in a STEM field and/or some experience related to STEM. Pseudonyms are used to identify participants.

Results

Results are organized by research aim and include finding highlights from on-going analyses. The data sources that informed these insights are from multiple data sources – interviews with child(ren) and caregiver(s), video recordings of in-person sessions using stand-alone cameras, and video recordings of at-home interactions with the engineering kits through a tablet and Sibme, a video-app created for professional learning, coaching, and collaboration.

Aim 1

The purpose of the first aim was to examine features of the program that best support participation and implementation of engineering design practices among caregivers and children. To date, the areas of focus to address this aim include (a) identification of a problem and brainstorming generation process, (b) patterns of interactions between caregivers and children during the monthly sessions, (c) engagement with material and tangible resources, (d) STEM moments of caregiver-child interactions while participating in the engineering kits, and (e) use of discussion prompts from the engineering kits. Findings from each will be briefly discussed.

<u>Ideation</u>

The idea generation process offers potentially interesting insights into children's thinking as engineers, as they engage in this process differently than adults [24]. Initial study results have begun to demonstrate a relatively consistent and powerful influence that adults, both family members and non-family members (e.g., engineers), have on the ideation process of children. We noticed that children began with and are excited by larger, complex problems or challenges, but are purposefully guided and influenced by the more systematic and intentional thinking of adults who were present. While the seeds of ideation began with the child, it appeared that greater amounts of adult thinking and problem evaluation was ultimately undertaken *through* the child, in the form of strategic questioning and statements. For example, how one student participant began to position herself as leading the idea discussion through 'I statements' and also positioning herself as a key member of her family and home environment all stemmed from specific questions directed at her from present adults. In earlier dialogue, the engineer made statements such as *"How do we think this is going to move?"* and "*What was your idea for that? Let's think about this…"* despite the ultimate project idea that was adopted having originated from an adult volunteer in the program.

<u>Patterns of interactions</u>

In this study, time-window sequential analysis of 10-second intervals was conducted to understand how the presence of facilitators during the monthly sessions changed caregiver-child interactions [25]. Finding revealed that the presence of a facilitator was 1.3 times more likely to led to a change in caregiver-child interactions during the 10-second window. These interaction changes can be considered either positive or negative. A typical negative example was the dyad interaction changed from parallel/shared, child-dominated or parent-dominated to none when a facilitator asked questions. When being asked a question, especially general questions (e.g., asking family dyads to explain their prototype), either caregivers or children stopped their making progress in order to respond to the question. In contrast, asking specific questions was less likely to interrupt dyads, and specific questions may contribute to the development of prototype idea or advance the practice. For example, a facilitator observed Zac's drawing and said "you are designing a swing set right now. Is this a brand new swing set or an existing one you are making changes to?" Questions like this can be addressed with short answers so participants did not need to stop their current work in order to answer others' question. Engaging dyads in off-task conversation also led to a negative change. This occurred more often between caregivers and facilitators, especially when empty seats were available by the working station of a dyad. Similarly, sharing relatable experiences with or making suggestions to caregivers only were more likely to result in limited interaction between caregiver and child as the children were often "gazing off."

Material and tangible resources

Working on an engineering activity, children apply ideas and tools to transform materials according to a well-defined goal. However, the role materials play in supporting children's' design thinking and communication are less understood. Findings highlighted that although materials were introduced to children when they were about to develop a solution to their self-identified problems, children further used materials to facilitate engineering practices beyond prototyping. For example, we observed that children and other facilitators used materials to communicate their ideas and concepts. Initial insights also demonstrated that children often proposed creating objects that were beyond their knowledge about materials and skills to hand them. For example, one child's knowledge of robots was limited to the human-like robots, which is often the common or dominant representation of robots in science and technology. We expanded her understanding about robots by introducing the Roomba as a way to create her prototype. We often had to consider caregiver and child's knowledge and skills of materials, as well as a balance between complexity and simplicity when suggesting materials.

STEM moments

This case study aimed to examine interactions between caregivers and children in their home as they engaged with the engineering kits that have potential to support children's foundational understanding of STEM concepts and skills. Three types of STEM moments were identified (a) teachable moments, which represented the time caregivers shared key concepts and skills in STEM subjects through verbal and non-verbal communications; (b) building-up moments, illustrated problem-solving and discussion processes when caregivers and children faced challenges; and (c) synthesizing moments represented consolidation processes in which immediate understanding of STEM concepts and skills occurred through cumulated knowledge and experiences throughout the activities. As such, these moments were not interdependent of one another. Furthermore, these STEM moments (1) were facilitated by questions by caregivers and children, (2) became engaging by exploring properties of the materials, (3) encouraged children to try again after failures, and (4) extended students' understanding of STEM concepts and skills using examples from their daily life. Conversely, other factors that mediated the STEM moments in more unproductive ways were (1) caregivers' approaches towards the provided instruction cards (e.g., using as a formal guideline they should follow), (2) inappropriate materials, and (3) missing or ignoring opportunity to hear caregivers' or child's feedback.

Discussion prompts

We examined different roles that caregivers took on during the implementation of the discussion prompts in the at-home engineering kits to organize families' engineering learning activities. The research team identified episodes where families utilized the discussion prompts and transcribed families' talks sparked by the discussion prompts. We further coded utterances of families' talks using the coding scheme by [26] with three elements: (1) engineering practices, (2) caregiver-child talk types, and (3) interest. Three roles emerged from our preliminary findings from six family cases: caregivers as *monitor*; caregivers as *mentor*; caregivers as *partner*. While faithful implementation of the prompts by caregivers who took on the role of *monitor* was supportive towards engagement in engineering practices, the asymmetric relationship in which the caregiver was positioned as the knowledge validator seemed to echo the rhetoric of hierarchy. Caregivers who took on the role of *mentor* demonstrated that moments of learning opportunities that emerge from the child's inquiries may not be taken up just-in-time. The on-the-fly support from the caregiver enabled the families to co-construct a working prototype; however, questions remain as to whether the caregiver's support also enabled the child learner to take ownership of the prototype. Caregivers that took on the roles of *partner* demonstrated that caregivers' active participation to learn and motivation to guide their children in inquiry process can be hindered when children's motivation and goals are not aligned with that of the caregivers. Our findings highlight the importance of situating the at-home engineering challenge as an opportunity to construct and evaluate knowledge rather than simply completing the challenge.

Aim 2

The goal of the second aim was to examine changes in children's engineering identity through engaging in engineering design practices with caregivers. Specifically, we addressed the following research question: How are children positioned to be engineers (or not) by caregivers and engineers within an engineering design process? We utilized identity work and identities-in-practice of Tan et al. [27] and Tan and Barton [28] to frame this study. Results highlighted contrasting cases in how two children, Walt and Cindy, were positioned as engineers within their individual projects. Walt was positioned as the "bigger picture" or idea person, as well as a researcher during the brainstorming stage of the engineering design process. He often leveraged sketches/drawing to share his thinking with others. As the project transitioned to prototyping, Walt was often positioned as an observer as he had limited access to the materials and tools, and during this stage, being an engineer was paying attention to what Mac (caregiver) was doing and inserting his ideas verbally. Conversely, Cindy was positioned and positioned herself as the expert and project manager of her project. This occurred throughout the design process from ideation to testing and redesign. She often leveraged her notes that included such things as measurements and a blueprint of her house. Being an engineer in this context for Cindy also included precision and doing computations by hand/paper-pencil as opposed to using a calculator/tablet.

Aim 3

The intent of the third aim was to examine shifts in caregivers' views of engineering, views of their children as engineers, and ways to support their child in engineering design practices. Insights gained from interviews conducted with caregivers at the conclusion of program will be discussed below, as well as a study that investigated the roles that caregivers played in developing and supporting their children's learning experiences as engineer during the monthly sessions.

Interviews

First, in the interviews, a few caregivers expressed gaining a new perspective of engineering and a new level of respect for engineers by participating in this program. As stated by one caregiver, "I think the program did broaden my idea that engineering isn't really a foreign thing, it's an everyday kind of experience. And it made me think about how often we do problem solve in just day-to-day living and modify things or how to think about when an issue around the house." She provided examples such as engineering a toilet that's not running appropriately or a cabinet door that is not closing right." Another caregiver was intimidated before the program started, but felt more confident in herself as an engineer by the end of the program. Second, becoming confident as an engineer and with the engineering process was also voiced by caregivers when reflecting on how their child(ren) had grown within the program. As an example of the former, "Chari really fell in love with something that she always felt elusive and always felt that she could never be a part of. . . her confidence built overtime…I was able to see how Chari could have a future in the field." Caregivers explained how their child(ren) gained skills and practices in how to think, problem solve, and collaborate, as well as learn how to be patient and overcome failures. Third, caregivers talked about this program shifted their interactions with their child(ren) – being more detailed and understandable when explaining how things work, providing space and opportunities to learn through trial and error, reconsidering the types of questions asked, and asking their child(ren) for help when repairing something.

One expected finding from the interviews, and unrelated to any of three aims, was that the majority of caregivers shared how this engineering design program afforded them time to spend with their child(ren), as well as make connections with their child(ren). As one caregiver stated, it allowed her a space to enter into her son's domain. "…having to do it as a family brought me closer to Zac, and to his mind, and to his world." This was dedicated time and space that was often spent on the chaotic day-to-day tasks. As stated by another caregiver, "I guess the most thing that I got out of the program is that it gave me a chance to do something with my kids because there wasn't a lot of time that was put in to doing things with them. Between me going to work, them at school, coming home and running over here, running over here, trying to prepare dinner or whatever, again like that bonding experience with the children."

Caregiver roles

Utilizing symbolic interactionism and role theory [29], we examined three case studies of caregiver-child dyads and the roles that caregivers enacted while working alongside their child on their family-generated engineering project. Further, we investigated how these roles were (re)shaped by decisions of the research team and interactions with researchers, engineers, and specialists. The three caregivers enacted multiple, yet different roles, in supporting their child from the beginning to the end of their projects (e.g., project manager, lead engineer, facilitator, observer and social broker). As a summary example, Mac often enacted the role of project manager and utilized his son's strengths as he provided opportunities for James to share his many ideas, conduct research, and explore materials (e.g., micro:bit). As a social broker, Mac supported James in articulating his ideas about the project to others. Results also highlighted how the choices made by the researchers before the program, such as what material was provided at each table, informed each caregiver's role in different ways - as lead engineer (Mac) or facilitator (Tanya) or outsider (Una). Further, caregiver's roles were shaped by who else was part of the interaction. For example, one volunteer maker seemed to dominate the conversation, which positioned Tanya as an observer.

Discussion

We will frame our discussion and conclusions by highlighting similarities and differences within each aim, and then across the three aims. To begin, we summarize research aim #1 by addressing the question, what features of the program best support participation and implementation of engineering design practices among caregivers and children? Alternatively, we consider what features of the program did not support participation and implementation of engineering design practices among caregivers and children. We contend that the significance of these findings contributes to the ongoing conversations about how to create environments that support families in creative and collaborative learning around STEM disciplines such as computing and engineering [30]. During the monthly sessions, one key feature was to simplify the complexity of the self-identified problem. Purposeful guidance (e.g., questions) and intentional thinking (e.g., child prior experiences) of caregivers and engineers supported the child in developing a problem that was achievable. Another attribute that supported this was material suggestions and constraints often based on the caregiver and child's knowledge and skills of available material (e.g., micro:bit) and cost of material. Additional features that supported caregiver-child interactions included exchanges with volunteer engineers in which specific questions around the project were posed and moments in which the engineers shared relatable and career-specific experiences. On the other hand, there was a tendency for volunteer engineers and makers to engage in off-task conversations that diminished the interactions between caregiver and child. Posing very general questions (e.g., How's it going?) were also likely to stop caregiver and child's engagement in their project as opposed to the specific questions as noted above in which the response was given while continuing their engagement in the project. As concluded in the caregiver roles study (aim #3), interactions with engineers and makers may position caregivers as outsiders.

Engagement with the engineering kits in home environments also highlighted a feature of the program that does and does not support participation and implementation of engineering design practices, moments in which lacking access to a facilitator may shift the interaction [31], as well as caregivers comfort level with the engineering kit [32]. Interactions were often framed by the pedagogical moves of caregivers and mediated by the materials, instructions, and discussion prompts provided within each kit. For example, for some caregivers the instructions served as a formal step-by-step process that had to be followed and led to an imbalance in power in which the caregiver was positioned as the knowledge validator. As such, caregiver-child dyads are participating in engineering design practices through the implementation of the kits, but the outcomes of our findings raise questions as how to facilitate interactions that is more balanced or interactions in which the caregiver supports the child's appropriation of engineering ways of acting and thinking.

The second research aim addressed the question, how are children's engineering identity being shaped through engagement in engineering design practices with caregivers. We presented two contrasting cases in which one child was positioned as a capable engineering participant (i.e., Cindy) while the other child was positioned as an idea-only engineering participant (i.e., Walt). The significance of these findings lies in the lack of research on how children's identity in a STEM field is shaped by their caregivers in informal contexts [33], an environment in which children may not feel constrained and bounded by structures and norms of formal contexts (e.g., classroom; [34], [35]). Therefore, this study begins to attend to what counts for children's development of an engineering person in a setting with their caregiver(s) in which the roles of parent and facilitator or educator are blurred.

The third research aim addressed the following question: How did participation in the family-focused engineering program impact caregivers' views of engineering, views of their children as engineers, and ways they supported their children in engineering design practices? We regard the results from this aim to be promising as we noted positive shifts in caregiver's perceptions and support of their children as engineers, which will directly and/or indirectly shape their children's perceptions, interest, and involvement in similar activities and disciplines [6], [21]. Caregivers expressed a newfound understanding of engineering, particularly in how engineering is something they do in their daily lives. They articulated changes in their child's confidence throughout the program as they were engaged in practices and skills common to engineers. Further, caregivers noted how participating in the program transformed ways they interact with their children in other contexts (e.g., types of questions posed, allowing experiences with trial and error). Lastly, we observed how caregivers enacted multiple roles in supporting their child throughout the project. These roles fall along a continuum from providing more assistance and hands-on support to less assistance and hands-on support [36], [37]. From an outside perspective, some of these roles may seem to position the child as having limited ownership of their project. Nevertheless, we agree with Sadka and Zimmerman [37] and Sadka et al. [38] that the roles that caregivers enacted are based on their awareness and/or knowledge of their children, as well as well as their own understanding (or not) of the concepts and skills needed to advance the project.

Conclusions

In our third year, we continue our research efforts to address the objective and three aims of this NSF funded grant. We have made three major shifts based on results from the previous two years and our inability to conduct in-person human subject research. One, we revised our engineering kit instructions to include a set of instructions for children and a set of instructions and additional guidance for caregivers to support their child(ren). We also focused more intentionally on different phases of the design process and relevant engineering careers. Two, we developed appropriate scaffolds to support children's and caregiver's ideation of the problem. Three, we supported families' engagement in the engineering design process remotely, through dropping off engineering kits at their home or in collaboration with libraries, as well as hosting virtual sessions.

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