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Motives, Conflicts and Mediation in Home Engineering Design Challenges as Family Pedagogical Practices (Fundamental)

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Abstract

Much is known about the importance of the family as a learning environment in STEM education [1], but less is known about conducting engineering design challenge activities in home environments. Although many studies highlight the development of STEM concepts and skills, more research is needed to understand how to support this development through caregiver-child interactions at home. This study aims to (a) investigate caregiver-child interactions that support the development of child(ren)'s STEM conceptualizations and skills in engineering design challenge activities within family pedagogical practices, and (b) examine caregivers' pedagogical expectations within family pedagogy. Guided by Vygotsky's cultural-historical view, the authors analyze child(ren)'s development of STEM conceptualizations and skills in parent-child interactions, with a focus on motives, conflicts, and mediation.

Seven families with nine children (grades 1-5) participated in three to five engineering activities over six months. The research team sent at-home engineering kits that contained an instruction card, materials, and tools for engineering challenge activities in five engineering disciplines. Caregivers were instructed to video-record their engineering activities, creating approximately 100 hours of video data. Then, caregivers participated in in-depth online interviews about their pedagogical expectations in educating children, specifically in STEM education. Qualitative findings from the home engineering data indicated that conflicts occurred (a) between caregivers' suggestions and children's ideas, (b) in misalignments between children's readiness to take risks and caregivers' level of facilitation, and (c) between caregivers' and children's motives. From the in-depth interviews, caregivers' narratives illustrated their pedagogical expectations in STEM learning as (a) broadening the child's understanding of engineering and STEM domains, (b) developing independent learning skills through quality family time, and (c) nurturing thinking and problem-solving skills in daily conversations. For the first theme, caregivers commonly highlighted the value of failures and trial-and-error in lifelong education. Secondly, caregivers noted the importance of independent learning skills through their families' life experiences. The final theme was caregivers' awareness of the how their communities valued STEM skills.

Introduction

The home environment as a place of informal STEM learning is rarely investigated, although prevalent research reports association between children's STEM education and caregivers' socio-contextual factors, such as education level, income level, ethnicity, and gender. Caregivers' involvement and their impact on children's education is a significant topic in educational research. The National Science Teachers Associations (NSTA) states that caregivers are critical educational partners in creating a supportive learning environment [1]. The interaction between caregivers and children is recognized as a way of facilitating children in STEM learning in a collaborative setting. Bruner [2] suggests that "one of the most crucial ways in which a culture provides aid in intellectual growth is through dialogue between the more experienced and less experienced." However, one critical barrier to conducting research in home environments is invasion of privacy [2]. Thus, the investigation of STEM activities between caregivers and children have been mainly conducted in museum settings. An extensive body of research highlights the impact of caregiver-child interaction on children's learning and remembering [2], children's socioemotional development and metacognition [3], and caregivers' and children's different strategies in facilitating conversations [4]. This study builds on prior research to engage caregivers and their children in problem-solving, critical thinking and hands-on engineering design challenges and investigated caregivers' values as educational partners and caregiver-child interaction. We asked two research questions in this study.

1. What beliefs, values and expectations did caregivers have when they participated in the home engineering design challenges?

2. What conflicts did caregivers and children face during the home engineering design challenges?

Caregivers' involvement and their beliefs, values, and conflicts in STEM education

A national survey about parents' involvement in their children's learning [5] reported that about 90% of 1,442 parents who have at least one child between three and six years old showed confidence in teaching social skills, literacy, and mathematics at home, while science was markedly different. Approximately 70% of them felt that they had ideas about how to facilitate their children's science education at home. The imbalance between overall confidence in teaching and having ideas about how to facilitate science describes two critical factors in caregiver-child interaction in STEM education: caregivers' STEM knowledge and their attitudes toward their children's STEM learning. Caregivers' explanation style and confidence in STEM activities varied by their confidence in STEM knowledge [7]. One of the biggest challenges in developing caregiver-child programs is that caregivers do not have accurate understandings of STEM domains [8]. This is associated with reluctance in explaining STEM concepts and misconceptions by the students [9]. However, caregivers' values and their acknowledgement of the importance of STEM education were related to children's interests and career aspiration development in STEM fields. Youth with understanding of their caregivers' educational value towards science were more likely to have a career goal related to science [10].

While there is literature describing caregivers' involvement and their values towards STEM education, we know less about conflicts between caregivers and children in STEM learning activities. Anderson, Piscitelli, and Everett [11] summarized three types of conflicts in agendas between adults and children in science museum programs as follows: (a) competing agenda of content: children are interested in a specific content of a painting (e.g., a volcano) but adults focus on the aesthetic aspects of painting, (b) competing agenda of mission: children are interested in their favorite topics (e.g., dinosaur) but adults focus on the overarching theme of the exhibit, and (c) competing time: children spend more time on their favorite subjects, but adults divided their time between their focuses. We conjecture that these competing agendas may appear in at-home caregiver-child interaction in STEM activities. These competing agendas may affect students' motivation to participate in learning activities as well as interactive patterns regarding who takes the leading role.

Informal STEM Learning Opportunities

Productive informal STEM education aims to engage "young people in STEM learning and actively [support] inclusion and [broaden] participation by young people in STEM learning" [12]. Science museums provide a wide range of informal STEM education programs for children and their families. Positive benefits of these programs have been widely documented, but some researchers argued that science museum programs reflect dominant cultures [13]. Families in underrepresented populations can be isolated from this content. STEM night programs, another popular informal STEM program, encourage local family involvement. Educators attempt to reflect the local population's characteristics such as ethnicity [14] and guide families' engagement in problem solving based on STEM concepts. Competitive informal STEM programs such as science fairs or math counts are other formats of informal STEM activities. These programs emphasize caregivers' participation in support of their children. The positive effects of these programs include an increase of STEM knowledge, STEM career aspiration, social skills, and learning behaviors [12]. However, these effects are associated with the demands of hard work. Students in higher grade levels expressed concerns about the length and complexity of the programs. Participants are encouraged to continue the activities and deepen their knowledge in home environments, but investigation of STEM activities at home environments rarely happens [15].

Perspective

Our work is guided by Vygotsky's cultural-historical theory, which explains the interplay of a child's development between natural development and cultural development. From this view, a child's learning is interpreted as a result of the interactions among the values, expectations, and aptitudes in the culture. A child is an independent individual who "takes something from culture, assimilates something, and takes something from outside" [16]. Applying this view to interactions between caregivers and children in an engineering design challenge activity provides opportunities to rethink roles of the more knowledgeable one and his or her support for the student within the zone of proximal development [17].

This study is also influenced by the work on the collaborative nature of the engineering design process. The Next Generation Science Standards (NGSS) [18] proposed three steps to the engineering design process (define, develop solutions, optimize) that promote learners' understanding of fundamental concepts and skills in engineering. This model was designed for four different age groups: kindergarten to second grade, third to fifth grade, sixth to eighth grade, and nineth to twelfth grade. For elementary-aged children, the Engineering is Elementary (EiE) design process model further suggests five steps in the engineering process: ask, imagine, plan, create, and improve [19]. This model is popular because of its potential and applicability to provide detailed support at each step for younger learners. Both models emphasize the iterative process rather than linearly following the steps in each model. In our study, children worked through these steps back and forth or sometimes repeatedly to create their solutions. In a family context, caregivers and children took multiple approaches in collaboration to solve problems and, ideally, to design one refined solution.

Methods

Participants

Seven families with nine children participated in three to five engineering design challenge activities in their home environments over six months.

Table 1. *Participants*

Child (Pseudonym)	Age	Sex	Ethnicity	STEM activity experiences	Caregiver (Pseudonym)
Min	6	Male	Asian	No prior experience	Sook Hyun
Eden	6	Male	White	Gardening club	Amanda
Sara	9	Female	White	Gardening club and several programs	
Jin	8	Female	Asian	No prior experience	Yoon
Sol	8	Female	Asian	No prior experience	Han
Roberto	9	Male	White	Robot club and STEM night	Khun Karen
Billy	9	Male	White	STEM night	Jennifer
Edward	12	Male	Black	Several programs	John
Jack	10	Male	Black	Several programs	Carol

Billy's family

Billy completed five activities with his mother, Jennifer, who was an art teacher at an elementary school.

Eden and Sara's family

This was the first time Eden participated in long-term engineering activities with his mother, Amanda. Sara, Eden's older sister, completed four engineering kits with Amanda. The two children completed the activities individually. Amanda worked at a children's hospital as a counselor and ran a gardening club with local families. Eden and Amanda used their heritage language, English, throughout these activities.

Edward and Jack's family

Edward completed three kits with his caregiver, Carol, who was working in a non-STEM field and Jack completed three kits with his caregiver, John, who was teaching public health at a university.

Jin's family

Jin came to the U.S. when she was three years old. She is fluent in English but preferred to use Korean in these activities as researchers asked her to select a comfortable language. Yoon was a musician in Korea but is currently a stay-at-home mother caring for her daughters. She can speak English but used Korean during the activity.

Min's family

Min was fluent in English and used English at school, but he used Korean with his caregivers. Sook worked as a nurse in a hospital. Although she learned biology and other related STEM classes through her collegiate years, she did not participate in STEM education programs. She is fluent in Korean and can speak English. Hyun graduated college in the United States, worked in Korea, and returned to the United States. His job has no connections with STEM fields. He is fluent in English and Korean. Sook and Hyun used mostly Korean during activities but used English to read the instructions or repeat the prompts included in the activities.

Roberto's family

Roberto completed four activities with his father who worked in science education at a university and one activity with his mother who worked in a non-STEM field.

Sol's family

Sol's family came to the U.S. for her father's studies for two years. Sol had a surgery for brain tumor and was in the process of recovery during her participation in this study. Her mother, who had no STEM background, contacted the research team through Jin's mom to provide her more opportunities to learn STEM. Her father, Han, participated in this activity. He worked in the Korean government and had no experience with STEM-related education and teaching. Sol is fluent in English and Korean but used Korean with her father during the activities.

Study Context and Engineering Kits

Participants were recruited through local STEM Saturday workshops by the research team. After obtaining the participants' consents, the research team delivered an engineering kit to each participant's home. Families spent at least two weeks to complete each engineering kit. Caregivers were asked to record their activities. When they finished one engineering kit, the research team delivered the next kit. Five engineering kits were developed by the research team based on the Engineering in Elementary (EiE) [19] engineering design process. Each kit included an instruction card, the materials, and STEM tools. The instruction card that provided activity guidelines consisted of the activity and five parts: engineering task, a list of materials, instructions for making the process, kit-chats, and additional resources. Engineering tasks had an activity theme, such as delivering a package to your friend's window or building a roller coaster for the local amusement park. Kit-chats provided potential questions caregivers could use during each engineering design process. Caregivers were not asked to use or follow every step in the instruction card.

Data Collection and Analysis for RQ 1: Post-Interview with Caregivers

Caregivers participated in semi-structured, in-depth interviews after they completed three to five engineering kits. The research team developed five questions to examine caregivers' beliefs, values, and expectations throughout the home engineering activities (Table 2).

Table 2. *Caregiver Interview Protocol*

1. In what ways did you grow and change by engaging in this program?
2. In what ways did you see your child grow and change by engaging in this program?
3. How do you feel that this type of program adds value or is helpful in conjunction with your child's typical learning opportunities at school?
4. How did your interaction with your child(ren) around engineering change, if at all?
5. How will you continue to use what you learned in the program? How did your perspective on your home/school/community environment change based on your engagement in this program, if at all?

Approximately, eight hours of video data from the interview were collected and transcribed. Three themes were identified by thematic interpretation from the post-interview data.

Data Collection and Analysis for RQ 2: Post-interview with Caregivers and Children and Engineering Activities

To address the second research question, the first author identified three to four conflicts between what children wanted to do and what caregivers attempted to do based on three competing agendas by Anderson et al. [11]. This conflict also represents the different motives that guided the children and the caregivers. Second, these conflicts were decoded to understand if they were related to STEM concepts. Third, themes were drawn from the conflicts during the engineering design challenge process. Caregivers and children watched the edited video clips of these conflicts individually and were asked to answer the following questions: (a) What was happening in the video clip? (b) How did you resolve it? And (c) Caregivers: What were some challenges when guiding your child in this moment? Children: What verbal/non-verbal interactions with your caregivers (parents) helped you make sense of science, engineering, or mathematics concepts in this clip? In future, we will expand our analysis to the larger dataset that includes 11 families' engineering engagement and involve another rater to assess inter-rater reliability.

Findings

What beliefs, values and expectations did caregivers have when they participated in the home engineering design challenges?

Our analysis based on the interview data demonstrated three broad themes in caregivers' beliefs, values, and expectations around the home engineering design challenges: broadening the child's understanding of engineering and STEM domains, developing independent learning skills, and nurturing STEM skills that support children's growth.

Broadening the child's understanding of engineering and STEM domains

The caregivers in our study shared the expectation that they hoped to trigger their children's STEM interests and broaden their STEM understanding by participating in the home engineering activities. The caregivers' expectations were influenced by their prior experiences, career histories, and educational experiences. For instance, Jin's mother, Yoon, shared that she wanted Jin to learn about STEM domains that may encourage Jin to identify an interest in area STEM. Yoon explained:

> Jin said she wants to be a mother when she grows up. She likes playing with her little sister and is getting more interested in cooking and cleaning. I was wondering if I'm not a good female role model for Jin to develop her interests. I want to give her more chances to experience diverse career fields.

Yoon recalled that Jin was able to take a lead in developing and negotiating her ideas in the tennis shoe design activity. Jin said that "Mom, I would like to be a shoe designer to create a shoe to help others." Similarly, in another family, Hyun was pleased to see his child, Min, sharing questions and interests in STEM. While Hyun did not have a STEM degree or career, he had observed how STEM competencies are important in competitive job markets. He said that he would like to provide Min with various opportunities for STEM-related activities. Caregivers' hopes of triggering STEM interests was a common theme throughout the study participants.

However, caregivers did not push their children to become interested in STEM. Rather, they emphasized creating environments in which children would increasingly become interested in STEM throughout home engineering activities. Amanda shared a similar perspective on why she participated. She believed that learning occurred more often in informal settings than formal school settings. Specifically, she tried to motivate her children to understand STEM concepts in the garden, kitchen, and playground. She did not find many qualified engineering programs in her county, so she appreciated having the chance to participate in this home engineering activity. Caregivers perceived that participating in this home engineering program was more than just acquiring STEM knowledge. Rather, their descriptions called attention to family home engineering programs as a method for developing children's interest and understanding in STEM.

Developing independent learning skills through quality family time

All caregivers shared similar expectations for supporting their children to become independent learners and mastering self-directed learning behaviors. Particularly, in terms of engaging in the engineering learning process, Amanda and Yoon recognized that they valued independent learning because of their educational experiences. Yoon, as she learned from her mother, thought that her role was to prepare Jin to do tasks by herself. From leading the children's gardening club, Amanda learned that every child has potential to be a scientist. She shared that participating in this home engineering program would support her children to make possible discoveries and connections to scientific knowledge when appropriate questions and tools are provided. She further explained that she used various types of questioning strategies in home engineering activities to encourage her children to develop their own ideas and independent learning skills.

Caregivers also shared that the activities provided opportunities to connect with their children through quality family time and one-on-one interaction. Jennifer and Carol experienced changes in their concerns about the time. As working mothers, both had experienced difficult time constraints since the pandemic started. Carol shared:

> I began to enjoy the time that the kids saw growth in really working through problems using their critical thinking skills in the time we got a chance to spend together working through those problems, as it relates to the different activities. So it was great to see the kids really grow in more of an education sense, from each session that we participated in. So I would say how it's changed is I had one way of thinking about it. That could be a great time for us to bond. But also as a parent, being able to really see the educational growth, I would say, for my kids, from the first time we began this process, up until now.

From Vygotsky's perspective, children's cognitive development occurs during interactions with adults or a more knowledgeable person. Findings from this study supported Vygotsky's view, but also highlighted the influence on caregivers' perceptions. Five caregivers in this study described the influence of observing children's growth from interactive engineering activities on their own perceptions of the value of home engineering activities. This growth encompasses failures, testing, and retesting. Hyun felt uncomfortable seeing Min's hesitation and his failure to test the prototype in the beginning. He tried several approaches to help Min reduce the stress he felt from failures. Then, he observed that Min was able to learn select new strategies to solve problems. Hyun experienced his own growth in observing Min's challenges as a parent. Similarly, Karen reminded Roberto that there is no right or wrong answer in engineering activities. Accepting risks and improving the prototype through failures are the important values in engineering that encourage children to attribute failures to process than their ability [19]. Caregivers valued being able to observe children's growth through engineering activities in their own homes.

Nurturing thinking and problem-solving skills in daily conversation

Furthermore, six caregivers expected to see children’s thinking and problem-solving skills through home engineering activities, and they observed improvement of these skills. Caregivers recognized many signals about how children used various thinking and problem-solving skills in engineering design activities and how they applied these skills to real world problems. John observed that Edward and Jack could “think through different problems in different activities.” Thinking is a complicated process which requires various skills [20]. Therefore, using different thinking skills indicates that children are growing in these areas. Developing the power of thinking is evidence of intellectual growth [20] that entails problem-solving skills and motivation to explore more content in this study. Billy took extra steps to illustrate his zipline design using materials around his house. Eden emailed a university project team to identify a better material for preventing germ transmission. This finding suggests that the children took the initiative to practice problem-solving skills while they were working through the engineering activities.

Three caregivers identified changes in their interactions with their children, as their children applied their thinking and problem-skills to their daily conversations. Carol shared:

> My interactions with them definitely changed. And also how we talk about things in life. Like there's an issue in life. Just something, an everyday issue. Our dumps always have all this trash out there or whatever. What could they do to solve that? And they're like, "Oh, we could this! Oh, we could do that!" That's how our conversations have changed, being more problem solvers than complaining about things too. So it's really gone into other aspects of our lives. But it deals with engineering because we think about the problem and what can you do to solve it?

Similarly, Roberto recalled the concept of gravity from the rollercoaster engineering activity when he played with Legos. Jin and Eden also brought concepts from their prior home engineering activities into later discussions and asked questions to clarify their understanding. These episodes suggest that caregivers have learned how to interact with their children in ways that encourage thinking and problem-solving skills, as well as in discussing STEM concepts. They experienced positive changes in their daily conversations that enabled these families to recall what they learned and build on it.

What conflicts did caregivers and children face during the home engineering design challenges?

Our analysis of families’ home engineering challenge activities—in tandem with the findings from the interview data—further illustrated that caregivers’ expectations and value of the home engineering challenges created conflicts with children in three ways: (a) between children’s ideas and caregivers’ suggestions, (b) between children’s readiness and caregivers’ facilitation and (c) between children’s unwillingness to try new things and caregivers’ support for independent learning. Three family cases demonstrated three ways in which caregivers’ expectations and values conflicted with children’s motives and needs.

Children’s ideas and caregivers’ suggestions

Conflicts emerged when children explored different ideas and materials and caregivers stepped in to provide suggestions. The engineering design challenge of this at-home project encouraged children to ask questions, address their ideas, and negotiate their ideas with caregivers in collaborative educational environments. In the interview, all caregivers were aware of the importance of taking the role of a facilitator rather than a teacher. Analysis revealed that caregivers had inner struggles to determine the most appropriate level of information to provide when they noticed that their children's ideas or solutions would not work. One example is from the puppy trainer kit activity with Edward and Carol when they were finding a mechanism to dispense one treat at a time. Jack explained his ideas and Carol asked several questions to prove his ideas. Then, Carol suggested drawing a dispenser design individually. Edward accepted her ideas after he compared his design with hers. Jack described this situation as "She gave me new suggestions. And they were good suggestions." Carol explained that:

> I think he had one idea of how he wanted to build it. And I'm like, "That's not going to work." But I didn't want to tell him that. And so that was my way of, "Well, you want to make it close knit. So how can you do that?" And then he still was stuck on how he wanted to do it. And that's me being very controlling, in a sense. I'm like, "Okay, you do your sketch. And I'll do my sketch. And then we can decide together which one is the best." And so that's what we did.

Like Carol, five other caregivers faced challenges in redirecting their children to change ideas and find appropriate solutions. Jennifer gave more flexibility to Billy in a similar situation. She encouraged him to make a prototype using his ideas to give him credit, then she suggested her ideas. Commonly, the caregivers said that their children never finished a project if caregivers did not actively negotiate ideas or fix the problems. This conflict describes Vygotsky's zone of proximal development (ZPD) which refers to "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance" [21]. Caregivers in this study were looking for the appropriate assistance for their child to move them through ZPD. On the other hand, bilingual families in this study experienced additional challenges with helping their children develop thinking skills as well as understand the process in both languages. In activity videos, Jin often paused while she was elaborating her ideas. Yoon jumped into Sol's conversation or confirmed and rephrased her ideas in English or Korean. Han also spent a certain amount of time explaining his suggestions and helped Sol explain her ideas in English and Korean.

Three caregivers attempted to apply a broader knowledge base in making and improving a prototype, whereas children focused on creating based on their understanding and creativity. Roberto and his mother were making a blooming flower using a care steering mechanism. They decided to make petals first and Roberto was cutting them. His mother immediately stopped him and asked him to make all the petals the same size. He did not understand why she wanted to make the same size petals but followed her directions. Sol's and Min's fathers shared similar experiences when engaging children in understanding broader concepts. This conflict is associated with the use of scaffolding. Although scaffolding is not mentioned by Vygotsky [21], this concept is interchangeably used with ZPD. Scaffolding refers to a process that empowers children to make strong progress in understanding and developing independent learning attitudes via a more knowledgeable person's assistance. The key to scaffolding is providing diverse and appropriate instructional assistance that meets the students' level of understanding and their needs. Examples from this study illustrated that caregivers sometimes skipped the process of scaffolding to achieve their goals.

Misalignment between children's readiness to take a risk and caregiver's level of facilitation

The second type of conflicts emerged when caregivers' level of facilitation was not in alignment with the children's readiness to receive, process, or use caregivers' questions or suggestions. Caregivers often used appraisal phrases such as, "I like that idea," "Good job," or "Awesome." Individual children, however, showed different levels of receptivity to caregivers' questions or suggestions based on their willingness to internalize the feedback. Differences in children's reactions were demonstrated more clearly when children felt their attempts did not work well. Sara found that her container was stuck in the middle of zipline and tried to fix that problem using caregivers' suggestions. When her father asked a question about the friction, she attempted to answer the question using her knowledge. Her answer did not correctly address the friction, but she negotiated her ideas with her father. Min identified negative emotions in his mother's questions and suggestions. He argued that "Mom, I told you not to ask me questions about what I do not know." Then, Min's father jumped in the conversation to relieve tensions between Min and his mother. Eden was looking for ways to turn on the LED lights on the rain gauge. Amanda knew that Eden needed to attach a bigger size aluminum foil between the lights and connect a cup to transfer electricity, so she proposed various questions to help him understand the concept of conductive materials. But Eden stopped engaging as he became overwhelmed by his mother's suggestions.

> Excerpt 1. Eden (child), Amanda (caregiver)
> ((Eden is stuck on figuring out the problem in connection between batteries and LED lights using alligator clips because LED lights were blinking, not staying on.))
> Amanda: Can I give you suggestions?
> Eden: If it is short. Mom's suggestions always made it complicated.
> Amanda: ((laughed)) No. I know it's tricky.

These examples reflect how receptivity takes a central role in children's interpretation of caregivers' feedback. In this study, the caregiver and child were placed in an intimate one-on-one learning environment. Children were asked to share their thoughts and feelings more frequently than in a formal classroom situation and caregivers had more opportunities to listen to children's thoughts. Noddings described teachers' role in this situation as "feel(ing) with the other" [22]. In this line of thinking, understanding children's emotion is another important aspect in facilitating children's development and participation in the engineering design process.

Caregivers also learned how to use questions or suggestions based on their understanding of the child's emotions. Amanda shared:

> Well, they tend to get upset if I tell them things don't work. And sometimes, if I do that, and they're intending to do something else, it just shuts things down, shuts the conversation down. So, I think by asking that question, it's more of encouraging them to

keep trying different approaches. Like, okay, well if you didn't get what you wanted with that, what else could you do, so that I'm not giving them the answer? And sometimes they come up with things that I haven't thought of, at all.

Caregivers were sometimes able to detect children’s body language to confront their hesitation and struggles. Children often could not answer caregivers’ questions when they asked about advanced concepts or complicated processes. Jack did not answer several of John’s questions about making a handle for the container in the zipline. Jack understood the questions but did not have an answer. He said, “Basically he asked me questions, and asked me how I was going to use that for my creation.” John noticed Jack’s struggles from his hand gestures and explained the STEM concepts directly rather than posing another question. These findings commonly emphasized understanding children’s emotions and readiness through various signals such as non-verbal language. Caregivers in bilingual families experienced dual challenges in understanding children’s readiness. Sol’s father and Jin’s mother often checked children’s understanding in Korean first, and then double checked in English, which helped caregivers know whether their children had challenges with understanding concepts or elaborating their ideas in Korean.

Caregivers’ motives and children’s motives

Conflicts also emerged when caregivers limited children’s time to explore materials or followed the guidelines closely. Caregivers’ expectations towards the at-home engineering design challenge as a learning opportunity often created conflicts with children’s playful engagement in engineering activities. All the children usually explored the materials by themselves at the beginning of the activity and engaged in making and testing during the activities. When children tried to play with materials that were not related to the suggested guideline or if they were doing something that was not connected to the next step, caregivers demanded their children to focus on the task and move to the next step. We present an excerpt from Sol’s family to illustrate this finding. In the following episode, Sol designed a paper roller coaster with tracks, a loop, and hills. She engaged in folding tracks and tested it with her little brother.

Excerpt 2: Sol (child), Joon (Sol’s brother), and Han (caregiver)
((Sol folds a cardstock and Joon watches her. Han folds a cardstock as well.))
Sol: What are you looking at?
Joon: Just looking.
Sol: Do you want to try? It’s fun. ((hands over a cardstock and folds three tracks))
Sol: Look! It’s rolling. ((rolls a marble on the track with Joon))
Han: Sol, it’s not play time. Did you fold all the tracks? How many tracks did you draw in your design?
((Han points toward the track on the design and Sol looks at the design. Sol and Joon do not listen to Han. Han asks her to have a seat again.))
Han: This is a good opportunity to make a roller coaster by yourself. They [project team] delivered the materials to our house. Do you remember when we went to the amusement park in Florida? You can make that roller coaster. Look at your design again. How many tracks did you draw?
Sol: Four or five.

> Han: Look at the instruction and see how many tracks you need again.

Children’s playful engagement also decreased if they perceived doing engineering activities as homework. Jennifer said:

> In the beginning, he was really interested. Oh, the first project, the second, and then when we still had the third, the fourth, the fifth, he was getting a little bit bored, more like it seemed like homework a bit. So even though I know it wasn't supposed to be, and I was trying to, "No, this is not homework. This is something that you're going to learn from it. This is beneficial." I tried to... Both my husband and I tried to show him that this is good for you, but it's just the... How can I say? The fact that he has to sit down at a certain time with us, even though he liked it after, it was getting him to the point of doing it. Because [we’d say] Let's do our project today Roberto, and he said, "Can I do it tomorrow?" So, I thought that he lost a little bit of motivation after the second project.

All bilingual families who moved to the U.S. with short-term or long-term goals emphasized educational priority in their family pedagogy. Caregivers were often concerned with the different scopes of contents in STEM activities between the two countries. They valued both countries’ educational approaches, but they especially appreciated this program as an opportunity to experience informal STEM education in the U.S. These expectations sometimes triggered a problem for caregivers when they decided how long they should allow children to explore contents or materials based on their interests. This challenge is in the gap between learning science and doing science [23]. Engineering activities in this study do not focus on just making a prototype. Activities were designed to engage students in the engineering design process. When children perceived the engineering activity as homework, their engagement turned into disengagement, which created a disconnect between doing engineering and learning engineering.

Discussion

Caregivers’ critical influence on children’s learning is not a new concept. Six themes emerged that explained (a) the caregivers’ values, beliefs, and expectation, and (b) the conflicts between caregivers and children in home engineering activities. Caregivers perceived the value of home engineering activities as broadening children’s understanding and interest in STEM. Caregivers play critical roles in developing interest in STEM for the youth [6], which was also evident in our study. For example, Jin’s mother was concerned that she might not be a good role model for developing Jin’s interest in diverse careers. She participated in this project to expose Jin to more STEM learning opportunities. Caregivers’ educational and career experiences influenced their decision to engage children in STEM through engineering activities. Although findings did not provide direct evidence of association between Jin’s mother’s values and Jin’s career interest, Jin engaged in engineering activities with her parents and then expressed she would like to be a shoe designer. This finding indicates that engineering design activities at home are appropriate for promoting children’s understanding of and interest in STEM.

Secondly, caregivers valued the home engineering design challenges as opportunities for quality family time while also fostering their children’s independent learning skills. Compared to many informal STEM programs in which children are dropped off, caregivers and children worked through the engineering challenges together without time constraints. In home environments, caregivers in this study were able to recognize children's non-verbal expressions and ask questions to clarify children's needs, which facilitated caregivers to gain a deeper understanding of their children's growth in thinking, problem-solving skills, and STEM concepts. The third theme of caregivers' expectations highlighted the role of family as a unit of interactions that magnified reciprocal influences in developing children's understanding and curiosity of STEM. caregiver-child interactions as shared experiences that enabled caregivers to understand their children and learn to support their children's enactment in STEM activities, rather than focusing only on children's engagement and learning. Additionally, caregivers valued the opportunities this informal engineering program provided for interactions with their children.

The findings about the conflicts between caregivers and children were consistent with the differing agendas of content, mission, and time reported by Anderson, Piscitelli, and Everett [11]; however, our findings highlighted nuanced differences in interactions between caregivers and children. Differences reflected challenges from caregivers' perspectives about what level of specific information they should provide, how often they used facilitation strategies, and how long they should allow children to explore ideas. First, children tended to elaborate their ideas, whereas caregivers sought for or already knew the answer to a solution. Caregivers employed multiple facilitation strategies to help children find solutions that required slightly more developed cognitive skills. This is consistent with Vygotsky's ZPD and how caregivers scaffold children to work through a task. All caregivers in this study were aware of the importance of the scaffolding that occurs during co-construction, but they struggled to find the most appropriate level of support. The second theme highlighted children's receptivity to caregivers' feedback. Children either neglected or refused caregivers' feedback when they felt the caregivers' suggestions made the problem complicated or irritated their feelings. Caregivers sought appropriate facilitation strategies to resolve these conflicts. The third conflict emerged from different goals of participation. Children tended to enjoy exploring the materials, whereas caregivers perceived participation as an opportunity for understanding and learning STEM. According to Witte [25], "A lot of Western parents assume we have to teach things to our kids, while a lot of museum staffers think exploring is more important and that parents should not lecture at their kids." Asian immigrant families also showed a similar pattern of emphasizing teaching their children, whereas children enjoyed their exploration.

Along with the third theme of caregivers' expectations for developing children's thinking and problem-solving skills, these findings support the importance of family-system studies. Systems theory in family studies has been utilized to understand children's physical and cognitive development through interactions with the complicated structure that highlights reciprocal influences between main caregivers and children [24]. Our engineering program was implemented within families' home environments, which magnified the reciprocal influences that caregivers and children could provide over time in their culturally familiar environments. Our findings described caregiver-child interactions as shared experiences that enabled caregivers to understand their children and learn to support their children's enactment in STEM activities, rather than focusing only on children's engagement and learning. Additionally, caregivers valued the opportunities this informal engineering program provided for interactions with their children.

Overall, this study was the first step toward an investigation of the nature of home engineering programs and conflicts in caregiver-child interactions. The study findings connect with theories and approaches in developmental psychology and social psychology that can be grounded on Vygotsky's approaches. It will be critical, in future studies, to deeply investigate the nature of home engineering programs in cross-cultural family settings that consider different ethnicities, socio-economic statuses, and disability levels.

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