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Caregiver-Child Communication of STEM concepts with Engineering Design Tasks (Fundamental)

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Abstract

Engaging in engineering design processes may serve as an everyday experience to support children's understanding and application of STEM concepts; yet, little is known how this may unfold between children and caregivers in out-of-school contexts. Therefore, in this exploratory study, we utilized an expanded version of the translation model developed by Lesh and colleagues [1] to examine family's communication of science and mathematics concepts within engineering design-based tasks. Participants in this study were seven caregiver-child dyads from four families. The data source for this study were self-recorded videos of each family engaged in various engineering design tasks, in which caregivers were positioned as collaborators and partners. We analyzed approximately 10 hours of videos that ranged from 35:24 to 1:06:31 minutes. We observed caregiver-child dyads communicate mathematics and science concepts and ideas through multiple representations (i.e., concrete, pictorial, symbolic, language, realistic, and gesture) and translations within and among representations (e.g., gesture-language, concrete-language) within the engineering process. In addition, we observed four purposes for the use of representational fluency of mathematics and science concepts between caregiver-child interactions throughout the engineering design process. The significance of this study lies in the new possibilities for children's development of mathematics and science concepts in out-of-school contexts while positioning caregivers in the role of educator.

Introduction

It is common for science, technology, engineering, and mathematics (STEM) concepts to be understood as distinct disciplines as opposed to transdisciplinary in nature. As such, research highlights the challenges involved with connecting the learning of concepts, skills, and practices across disciplines while also acknowledging the benefits of such an approach to identity development, achievement, and interests to name a few examples [2]-[5]. Engaging in engineering design processes may serve as an everyday experience to support children's understanding and application of STEM concepts [6]; yet, little is known how this may unfold between children and caregivers in out-of-school contexts. Therefore, the purpose of this exploratory study was to examine family's communication of science and mathematics concepts within engineering design-based tasks through addressing the following two questions. One, what are common representations caregivers and children use, and translate among, to communicate mathematics and science concepts with one another while engaged in engineering design tasks? Two, what role does representations and representational fluency of mathematics and science concepts play in supporting children's engineering design process?

In this study, we utilized the translation model of Lesh and colleagues [1] that emphasized five forms of representations: (a) concrete, (b) pictorial, (c) symbolic, (d) language, and (e) realistic. This model emphasized the understanding of concepts through student's ability to represent their thinking through the five representations, as well as their ability to move and translate between and among the five representations, which is defined as representational fluency [1], [7]. Articulating one's conceptual understanding through multiple representations has been discussed as an effective approach for the teaching and learning of STEM concepts and skills [8]. More recently, it has been argued by Simpson et al. [9] and Moore et al. [10] for the inclusion of gestural representations within the translation model. Research on embodied cognition has highlighted the role of gestures in shaping and representing individual's thinking, reasoning, and understanding of concepts [11], as well as supporting their ability to communicate ideas which may be challenging for students to describe through other forms of representation [12]. Therefore, we included gestural representation as an additional representation to Lesh and colleagues [1] original translation model.

Related Scholarship

Regardless of caregivers' own feelings and emotions towards mathematics and science, they are able to act as educators and support their children's knowing and doing of mathematics and science at home [13], [14]. Some of these opportunities to engage children as learners are not grounded in what may be considered formal or school-based ways of knowing and doing mathematics and science, but framed within everyday family experiences such as gardening, construction, cooking, and pottery, or even problem solving [15]-[17]. For example, when a cake turned out mushy, caregivers and children tried to find which ingredients caused the problem and fixed it through the problem-solving process [18]. More recent research has also shown how mathematics and science concepts are being developed through engineering design tasks with parents and/or caregivers [19], [20].

Research has highlighted the various verbal and non-verbal actions and behaviors that caregivers employ in their interactions with their child(ren). As an example, children's curiosity about why a flashlight is blinking was extended to collaborative caregiver-child discourse (i.e., language) on how the firefly produces light [21]. Caregivers to support their children through other forms of discursive practices - exploration, explanation [22], and encouraging children to evaluate findings and predict the cause [23]. Using one's body and objects have also been highlighted as an important factor for developing children's cognitive abilities [24]. For example, caregivers elaborated their thoughts about the design process using gestures [25]. Caregivers have also been found to use objects (i.e., concrete) to explain abstract concepts and/or confirm children's understanding of a concept [26]. As these few examples highlight, caregivers communicate with their children through different modalities and representations. Therefore, we expect to add to this research base with a focus on representational fluency.

Theoretical Grounding

Rogoff's [27] guided participation is rooted in the sociocultural theory [28] which emphasizes the importance of learning through interactions and experiences within cultural contexts. Guided participation places an emphasis on "communication and coordination" that include nonverbal interactions such as observation and reflection [29, p. 284]. Caregivers' role is to connect "children's present understanding and skills to reach new understanding and skills" and to support "dynamic shifts over development in children's responsibilities" [29, p. 8]. From this view, a parent-child dyad is a unit of interactive learning rather than isolated participant from the social context. Verbal and nonverbal interactions are windows to analyze the process of building mutual understanding around STEM concepts between caregivers and children.

Methods

The data for this study was collected as a part of a larger program focused on supporting family's engagement as engineers in their home environment. As part of the program, families self-selected and completed researcher-developed engineering kits. The kits included all needed materials and tools, but families were encouraged to also use materials and resources in their home environment. Instructional cards were also included that guided families through the engineering design process with photos, examples, resources (e.g., video links), and questions for caregivers to pose during their interactions. For this study, we focused on four kits – Rain Gauge, Package for Delivery, Blooming Flower, and Puppy Trainer - because of their potential to elicit mathematics and science talk within the engineering process. As an example, the rain gauge engineering task asked dyads to create a rain gauge to measure the amount of rainfall over a set period of time. They were challenged to create a simple circuit so that LED lights would light up when a certain amount of rainfall had accumulated (e.g., 1 cm=red light, 2 cm = green light). We have documented elsewhere how the shape of the cup and the support of caregivers served as a seed for their children's understanding of inverse proportional relationships [19]. The kits were not developed with an intent to evoke science and mathematics moments, nor were caregivers provided any training before interacting with their child.

Participants

Participants in this study were four families (1 African American; 3 White), seven caregiver-child dyads. Children were between 6-12 years of age with one self-identifying as female and six as male. Refer to Table 1 for specific demographic information.

Table 1. *Participant information*

Child Pseudonym	Caregiver(s) Pseudonym	Child Age/Grade	Child Gender	Ethnicity	Caregiver Information
Billy	Jennifer	9/4th	Male	White	Jennifer worked in an elementary school as an art teacher.
Edward	John Carol	12/7th	Male	African American	John worked in a STEM-related field. Carol was a graduate student.
Jack		10/5th	Male		

Eden	Amanda Steve	6/1st	Male	White	Amanda worked at a children's hospital. Steve worked at a biomedical company.
Sara		10/5th	Female		
Roberto	Khun Karen	9/4th	Male	White	Khun worked in science education and Karen worked in an administration position, both at a university.

Data Source

The data source for this study was self-recorded videos from each dyad engaged in one of the engineering design tasks – Blooming Flower, Rain Gauge, Package for Delivery, and/or Puppy Trainer. This amounted to 13 videos that ranged from 35:24 (min: sec) to 1:10:30 (hour:min:sec). It was not the case that these videos were collected in one sitting, but may span a couple of days. Table 2 highlights the dyad, the design task, and the duration of each video analyzed per dyad.

Table 2. *Video data collected from each dyad*

Child	**Caregiver**	**Engineering Task**	**Duration**
Billy	Jennifer	Blooming Flower	1:05:51
		Package for Delivery	1:10:30
		Puppy Trainer	42:50
Edward	Carol	Puppy Trainer	1:04:49
Jack	John	Package for Delivery	46:42
Eden	Amanda	Package for Delivery	36:05
		Rain Gauge	42:58
Sara	Amanda	Rain Gauge	36:44
	Steve	Package for Delivery	35:24
Roberto	Karen	Blooming Flower	48:07
	Khun	Package for Delivery	40:37
		Rain Gauge	53:05

Data Analysis

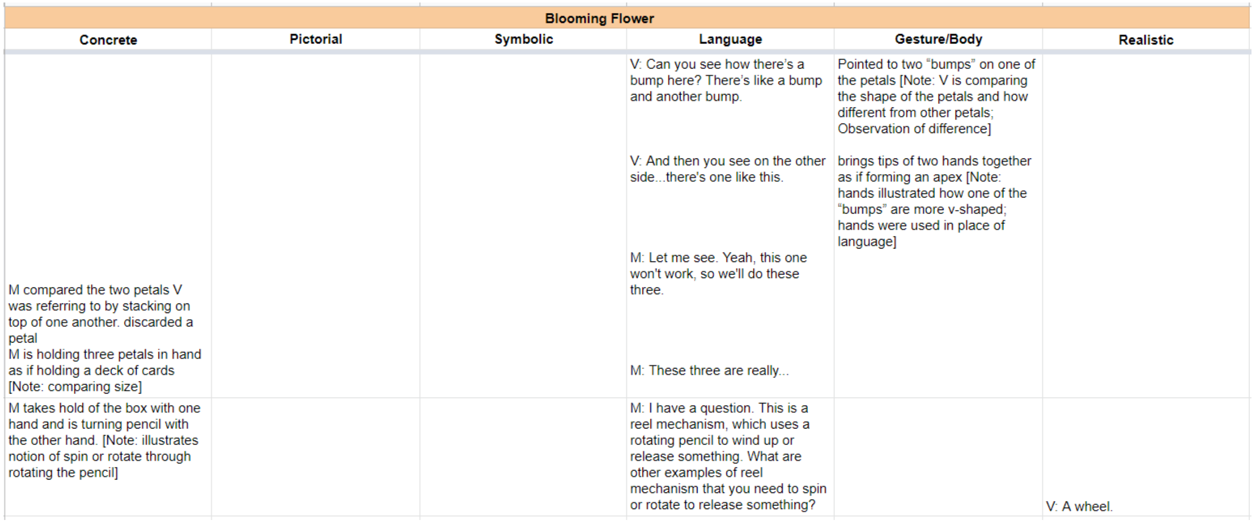
The first step of the analysis was to document the time range of the mathematics and science moments, as well as the concept(s) (e.g., force and motion, measurement) communicated between dyads during each moment. These moments were transcribed verbatim, including non-verbal actions. Next, each mathematics and science moment were analyzed using the updated translation model as described in the introduction and detailed in Table 3 below.

Table 3. *Six forms of representations with definitions and examples from this study*

Representation	**Definition**	**Example [Kit]**
Concrete	Concrete and physical models and tools to convey an idea or concept	Karen is comparing two petals by laying one top another. [Blooming Flower]
Pictorial	2-D representations - models, diagrams, graphs, drawings, etc.	Sara draws a line. Then from the end, makes half the basket (an arc) and then the same from the other end. [Package for Delivery]
Symbolic	Mathematical and scientific notation in written or oral forms of communication	Sara: “P: Yeah. The volume would be 1.2 milliliters.” [Rain Gauge]
Language	Oral forms of communication that do include mathematical or scientific notation	Jennifer: “I think ants do eat the pollen, the nectar, and they open up the flower, but they don't actually pollinate it." [Blooming Flower]
Realistic	Realistic, real-world, experienced contexts and metaphors	Kuhn: “They tell you not to play with stuff in the bathtub like a radio or a shower or a hairdryer. Do you know why? Because water conducts electricity and you can get electrocuted.” [Rain Gauge]
Gesture	Bodily actions, including iconic and metaphoric gestures [30]	Amanda does a back and forth motion with both hands as if raising/lowering a flag on a flagpole. Motion illustrates her thinking of a pulley system. [Package for Delivery]

We began by individually analyzing mathematics and science moments in one video – Roberto's Blooming Flower. We met to discuss our analysis in respects to the six representations, as well as discuss disagreements. Once we understood the six representations, each author analyzed a set of videos. We documented uncertainties to discuss as a collective. For example, one member of the researcher team questioned whether using one's hand as a ruler should be considered a concrete or a gestural representation. From her perspective the hand was being used as a tool. As a collective, we decided to code this a gestural representational as the action depicted a meaning for depth through spatial use of the body in relation to the concrete object of the container (see Figure 3 below). We placed the transcriptions into an Excel sheet (see Figure 1), identifying the type of representation. This allowed us to see the translations between and among the different representations, which addressed the first research question. For the second research question, we first documented the purpose of each representation and representational translations. This can be seen in Figure 1 following the word Note in both the Concrete column and the Gesture/Body column. Next, we synthesized the purposes for one dyad-kit before looking across all the data. As an example, the following synthesis statement captured the purpose of gesture-language from within one dyad (Roberto and Karen) and kit (Blooming Flower) highlighted in Figure 1 - "rotating gestures are representational actions that mirror language and realistic representations; how the prototype works and real-world examples of reel mechanisms."

Figure 1. *Image of analysis in an excel sheet similar to Moore et al. (2013)*



Blooming Flower					
Concrete	**Pictorial**	**Symbolic**	**Language**	**Gesture/Body**	**Realistic**
			V: Can you see how there's a bump here? There's like a bump and another bump.	Pointed to two "bumps" on one of the petals [Note: V is comparing the shape of the petals and how different from other petals; Observation of difference]	
			V: And then you see on the other side...there's one like this.	brings tips of two hands together as if forming an apex [Note: hands illustrated how one of the "bumps" are more v-shaped; hands were used in place of language]	
M compared the two petals V was referring to by stacking on top of one another. discarded a petal			M: Let me see. Yeah, this one won't work, so we'll do these three.		
M is holding three petals in hand as if holding a deck of cards [Note: comparing size]			M: These three are really...		
M takes hold of the box with one hand and is turning pencil with the other hand. [Note: illustrates notion of spin or rotate through rotating the pencil]			M: I have a question. This is a reel mechanism, which uses a rotating pencil to wind up or release something. What are other examples of reel mechanism that you need to spin or rotate to release something?		V: A wheel.

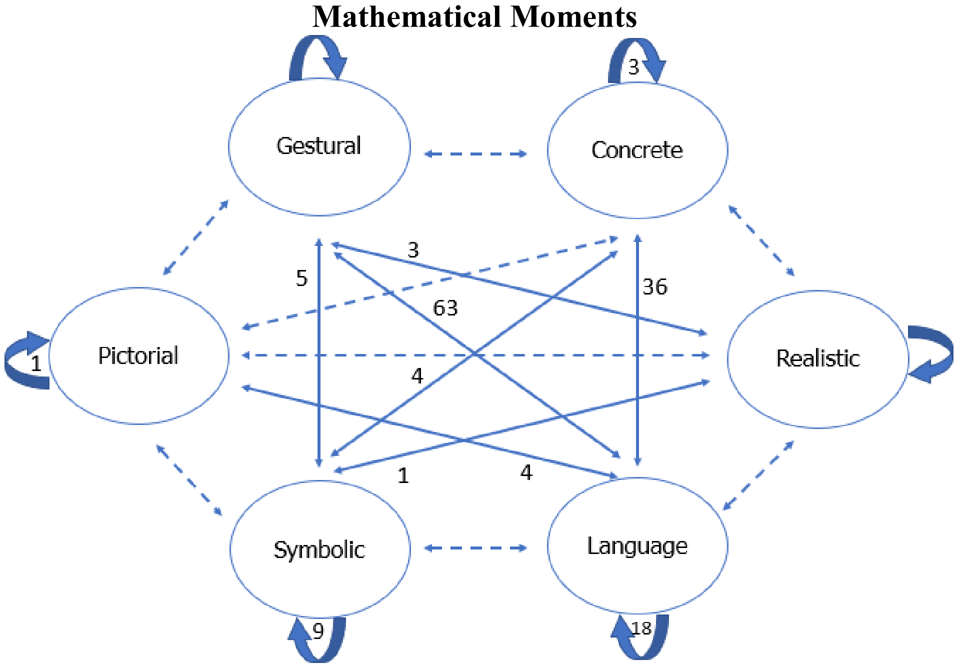
Results

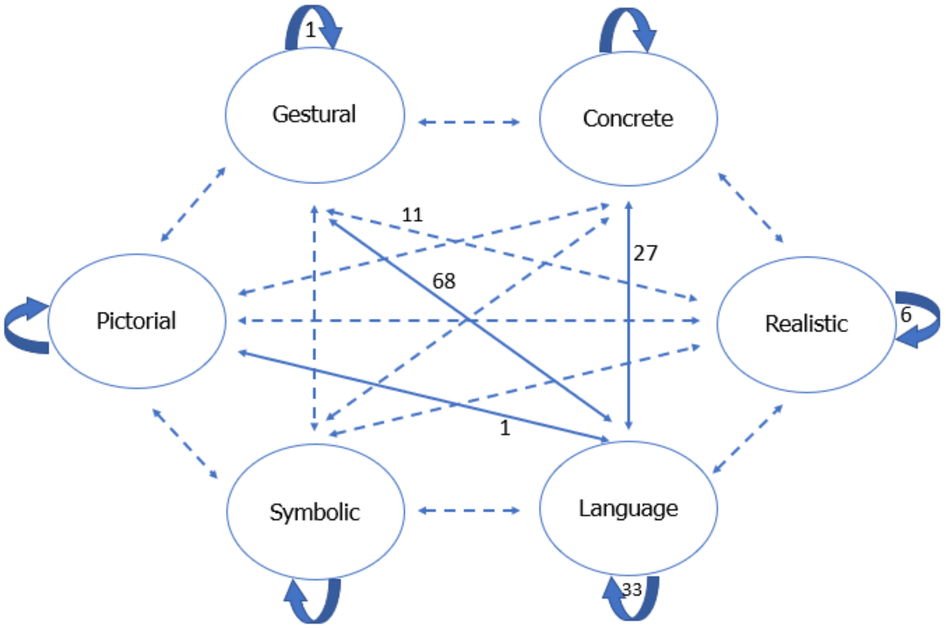
In the results, we begin by providing a visual overview of caregiver-child's mathematics and science representations. We highlight frequent and infrequent forms of representations, as well as provide representative examples to support. Next, we highlight how the use of different representations supported children's progress and process through the engineering task. We again include representative examples to substantiate the results from our analysis.

Research Question 1

Figure 2 displays the frequency of caregiver-child representations and translations between representations (e.g., gesture-language) by mathematics and science moments. As an example of how to read the two figures, we observed nine instances in which caregiver-child dyads communicating mathematical concepts through a symbolic representation. This is represented in the arrow below Symbolic in the first figure. As another example, we observed 11 instances of caregiver-child dyads communicating science concepts through gesture-realistic translations. This is seen on the arrow connecting Gestural and Realistic representations in the second figure. The dashed arrows indicate a lack of translation between two representations (e.g., pictorial-realistic).

Figure 2. *Frequency of representations by mathematics and science moments*




Science Moments

The use of gesture-language and concrete-language translations were common representations to communicate both mathematics and science concepts and ideas within the engineering process. This highlights the use of our body, as well as materials and tools, to support and clarify our language. As an example of gesture-language translation, we include a snapshot of Jack (caregiver) and John (child) talking about the functionality of the container they created to deliver an object from one side of their dining room to the other. Jack asked, “Is the size and the depth of the container appropriate? What’s the depth?” John responded that he did not know. Jack supported John’s lack in understanding of “depth” through both his language and gestures. “Think of it like how deep it is.” Jack placed his hand inside the 3D container from the top (see Figure 3A). Then he placed his hand through one side (see Figure 3B) and then again through the top (see Figure 3C) before stating, “So it’s pretty shallow.” John agreed, “Yeah, it’s pretty shallow.” In this instance, Jack’s hand acted as a ruler or a benchmark to mark the distance or depth of the container from different perspectives, from the top and from the side.

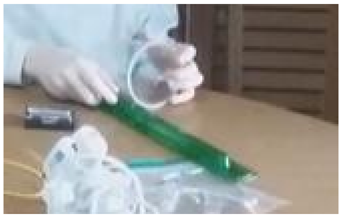
Figure 3. *Jack’s gestures to aid in understanding of depth*


Figure 3A Figure 3B Figure 3C

As an example of a concrete-language translation, Kuhn (caregiver) asked Roberto (child) how he would hold the ruler to accurately measure the vertical distance of a cup (or rain gauge prototype) that had a smaller circumference on the bottom than the top. The concrete representations afforded Kuhn an understanding of Roberto's thinking as Roberto used vague language such as "like this" or "like that maybe" (see Table 4). We contend it was easier for Roberto to show his thinking process around the "best" way to accurately measure the vertical distance of the cup than to rely solely on language.

Table 4. *Communication through concrete-language translations*

Idea	Verbal Communication	Non-Verbal Communication
1	R: Maybe we can do this. K: Okay	 *R laid the cup on its side and the ruler on "top", parallel to the cup.*
2	R: Or like that maybe. K: Okay.	 *R moved ruler so laying next to the cup, on the table.*
3	R: I don't think that would work because it's measuring the opposite way than we want to.	 *R positioned the ruler along the base of the cup as if measuring the diameter.*

4	R: So I think we should do it like…and I can see through it	 *R again positioned the ruler on the table and parallel to the vertical height of the cup.*

In terms of differences, realistic representations were more common in communicating science concepts, while symbolic representations were more frequently utilized in communicating mathematics concepts. As an example of the former, Billy (child) and Jennifer (caregiver) conducted research on the type of insects attracted by peonies, the flower they intended to model for their blooming flower prototype. Jennifer summarized what she learned through her online research. “This stated that peonies attract wasps and flies, the main pollinators of this plant. So, I think ants eat the pollen…or the nectar. And they open up the flower, but they don’t actually pollinate it.” Use of symbolic representations more commonly included units of measurements (e.g., 1.2 millimeters). For instance, after successfully sending a package across a fishing line (or zipline), Sara “measured” the length of the zipline by moving her body and arm from one side of the zipline to the other, then stated, “I’d say this is about 10 feet.”

Research Question 2

The analysis highlighted how language, symbolic, and realistic representations, for example, were used to communicate about and engage in science and mathematics ideas and concepts within the task (i.e., research question 1), but such representations were not necessarily used to support children’s engineering design process (i.e., research question 2). For example, there were three instances in which caregivers discussed why they do not want to be near water when it was lightening or use electrical devices near water. As stated by Amanda, “The crazy thing about water is that it’s a huge conductor of electricity. And that’s why if you are ever doing anything electrical, you don’t want to be around water. Because if there is enough electricity, it will zzzz.” In this case, the information shared may be considered a spontaneous science moment [31], but it did not impact the process and/or completion of the engineering task. Therefore, we focus on representational fluency to address this question. Representational fluency of mathematics and science concepts between caregiver-child interactions seemed to serve four purposes throughout the engineering design process.

One, caregivers and children used pointing gestures to provide direction and direct the other’s attention to material or parts of the prototype that would be needed towards completing the engineering design task. In creating the rain gauge, Roberto stated, “Okay, let’s go head and hook this up. Connect the negative to this.” Roberto pointed to an alligator clip. “And connect the positive right here.” Roberto pointed to aluminum foil. In this example, Roberto used both language and gestures to provide direction in how to create a simple circuit for the rain gauge to function appropriately. In a similar vein, dyads used material and tools (i.e., concrete representations), along with language, to provide direction in the creation of a prototype.

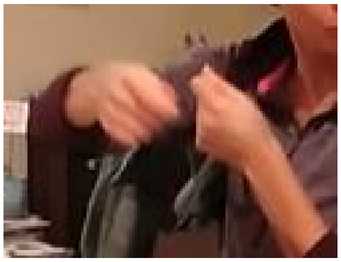
Two, dyads clarified vague language (e.g., “from here to here) using pointing gestures, as well as concrete representations. Consider the following statement from Eden in constructing the rain gauge. “It [cup] has markings right here. Right here. Right here.” The use of “right here” without another representation would not provide enough information for a shared understanding regarding the cup, a necessary object for the prototype. In this instance, Eden pointed to three areas on the cup to indicate where he noted manufactured markings on the cup. Similarly, the use of representational gestures was used to epitomize mental perceptions of ambiguous terms within the context of the tasks. For example, Karen determined that the petals for the Blooming Flower prototype “have to be more or less the same size.” This goal had to be met before Karen allowed Roberto to move forward in creating his prototype. In one instance, while Roberto was free-hand drawing the petals as noted above, Karen noted, “You want to do them approximately the same size. And like the stem should be the same width (see Figure 4A). Not one that is super thick (see Figure 4B) and another that is super thin (see Figure 4C).” Through her actions, Karen illustrated the width as a distance between her two hands that are parallel. Furthermore, in bringing her hands together in Figure 4, she illustrates the difference between super thick and super thin.

Figure 4. *Karen’s gestures to provide guidance on creating same sized petal stems.*

Figure 4A Figure 4B Figure 4C

Three, gesture-language translations mirrored creations and actions of a prototype. For instance, in explaining how the blooming flower worked, Jennifer noted, “You are going to use a pencil to create what is called a reel mechanism.” She exemplified a reel mechanism through making a fist with her right hand and bending her wrist so her fist moved down-up, down-up. In one specific instance, one caregiver, Amanda, repeatedly mirrored actions of a pulley system to provide her idea for how to deliver a package. Her language and gestures were framed as to elicit a response from Eden as opposed to stating her idea. Consider the following three exchanges (see Table 5).

Table 5. Gesture-language communication of a pulley system

Example	Verbal Communication	Non-Verbal Communication
1	A: Well something comes to mind to me, but it's not a zipline though. . . . What if it was in a loop, and yeah, you could zipline it across, but if it got stuck. Or you could secure the clippy there and you could pull from one side to the other. . . . But that's my idea, not your idea.	 *A does a back and forth motion with both hands as if pulling a string or rope.*
2	A: There's something I have in mind and there's no wrong answers. Think, what do you use to pull something? E: A rope.	 *A moved her arm in and out as if pulling something towards here. Hands are making a grabbing motion.*
3	A: A rope, right. When you were sitting in that chair, you were pulling yourself up. E: Oh yeah.	 *A moved right arm up, grabbing motion, then down.*

As exemplified in Table 5, Amanda refused to tell Eden the answer directly, but her actions (e.g., pulling a string, alternating movement of arms) and language (e.g., loop, rope) provided evidence that her approach was a pulley system.

Four, gesture-language translations were used by dyads to mirror abstract concepts (e.g., flow of electricity in creation of a simple circuit for a functioning prototype) and complex ideas used in the ideation and creation of a prototype. For example, Roberto was adding lines to the cup (i.e., rain gauge) to represent the vertical distance for the LED lights when Kuhn stated, "Now you do realize that…as we go up, what changes as we go up with this, which would make it slightly less accurate." Roberto's verbal response was accompanied with gestures to illustrate how the circumference gets bigger from the bottom to the top of the cup. In other words, Roberto understood this inaccuracy of the vertical distance between each line or LED light in relation to the circumference of the cup. As stated by Roberto, "Because it like curves up (see Figure 5). I mean like at the bottom it's the smallest and then it starts getting bigger and bigger and bigger (see Figure 6)."

Figure 5. *Roberto's gestures to exemplify "it like curves up"*

Figure 6. *Roberto's gestures to show how the shape of the cup impacts the vertical distance*

Discussion

The purpose of this exploratory study was to examine family's communication of science and mathematics concepts within engineering design-based tasks. There is a wealth of research that highlights the various verbal and non-verbal representations that caregivers employ to engage their child(ren) in STEM concepts, skills, and practices [22], [26]. In addition, recent research highlights the influence of caregiver STEM talk and interactions on their children's STEM identity and career decisions as an adult [32], [33]. These researchers found informal learning experiences involving STEM media and clubs/camps, for example, to have less of an influence. Results from research question one builds upon this research to highlight the complex nature of these interactions through multiple representations and translations between representations. For example, gesture-language and concrete-language translations were the most common form of communications between caregivers and children while engaged in an engineering design process. Results also highlighted the prevalence of realistic representations in communicating science concepts and symbolic representations when communicating mathematics concepts. While pictorial representations were scant in our results, this does not imply that pictorial representations were not common within caregiver-child's process. On the other hand, pictorial representations were not grounded in mathematics or science concepts. This may highlight the difference between a drawing and detailed design plans [34].

Results from the second research questions highlighted four ways in which caregivers and children utilized representations and representational fluency of mathematics and science concepts throughout the engineering design process. When multiple representations were linked together dynamically rather than independently, it appeared that children were able to solve problems in their design, support, enhance, and/or change their ideas, and gain a foundational understanding of particular science and mathematics concepts (e.g., simple circuit) throughout the engineering design process. First, pointing gestures were used to provide direction and direct one another's attention to material or parts of the prototype guided the development of the prototype through a more procedural approach than an exploratory approach. Alibali and Nathan [30] found similar results within interactions between teachers and students. In this study, this was more often observed when engineering tasks from this study were well-defined as opposed to ill-defined [35] such as the rain gauge. Second, the use of gestures and concrete representations were employed to clarify vague language (e.g., "Connect it right here."). In this example, language alone does not articulate one's thinking clearly and may hinder the engineering design process. We hypothesize that in some cases children do not have the language to articulate their thinking (e.g., alligator clip, negative charge) and must rely on other representations. Lastly, gesture-language translations mirrored creations and actions of a prototype (e.g., pulley system) that were often grounded in real-world experiences, as well as abstract concepts and complex ideas (e.g., flow of electricity) that children may not understand. As such, children and caregivers were provided with a visual cue of a simulated action and perception to make sense of language regarding science and mathematics concepts within the engineering design process [30], as well as support the development of the prototype.

Limitations and Future Research

In this study, our analysis included a small number of caregiver-child dyads and a small number of engineering tasks as facilitated through researcher-developed kits. As such, we acknowledge that the results are not generalizable based on probabilistic concepts, but may contribute and/or refine prior conceptual and theoretical frameworks [36] such as integrated STEM education frameworks by Kelley and Knowles [37] and Roehrig and colleagues [38]. As a research team, it is our intent to continue analysis of video data to examine the mathematics and science ideas and concepts communicated through representations and translations between representation between caregivers and children while engaged in engineering tasks. We contend that additional analyses will contribute to the transferability of the results to contexts that engage families with young children in an engineering task; contexts that are void of adults outside the family such camp counselors, museum educators, or engineers [39]. Lastly, future research should consider the mathematics and science concepts that are being communicated about spontaneously and/or serendipitously within different engineering design tasks [20], [31]. Initial insights from our analysis of these videos included congruency, spatial reasoning, parabolic trajectory, informal measurement, simple circuit, and force and motion. It may be argued that these spontaneous and/or serendipitous moments are planting seeds, or grain-sized cognitive resources, of mathematics and science understanding within worldly tasks [40]. This argument is further supported by prior research that highlights how individual's understanding of concepts is supported by multiple representations [7], [8], [10], [11].

Conclusion

In this paper, we illustrated how caregiver-child dyads communicated mathematics and science concepts through multiple representations, and translations between representations, while engaged in engineering design kits in their home environment; therefore, highlighting the transdisciplinary and humanistic nature of their communication [41]. As argued by other scholars [42]-[44], the results support the development and inclusion of engineering tasks as an approach to develop children's learning of concepts, skills, and practices between and across STEM disciplines. In addition, we contend that the results from the study highlight new possibilities for children's development of mathematics and science concepts in out-of-school contexts while positioning caregivers in the role of educator [45]. More specifically, engaging caregivers and their children in engineering design processes may serve as alternative and supportive approach to support children's understanding and application of science and math concepts outside required curriculum and content standards. As researchers and program developers look to the future, this work may contribute to the effective inclusion of caregivers into the STEM learning process.

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