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The Conception of Epistemic Practices of Engineering in the Home Environment (Fundamental)

Amber Simpson, Binghamton University

Amber Simpson is an Associate Professor of Mathematics Education in the Teaching, Learning and Educational Leadership Department at Binghamton University. Her research interests include (1) examining individual's identity(ies) in one or more STEM disciplines and (2) investigating family engagement in and interactions around STEM-related activities.

Ms. Sawsan Werfelli, State University of New York at Binghamton

Sawsan Werfelli received her undergraduate degree in English from Tripoli University, Libya and her Master's degree in Linguistics as a Fulbright scholar from Florida International University. She decided on pursuing her EdD after having worked in the field of education for 8 years. She is interested in social justice issues and inclusivity of education.

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Introduction

Current national policy documents in the United States call upon the integration of engineering design tasks in K-12 classrooms as a way to support children's understanding and knowledge of concepts and practices unique to the field. However, the difficulties in implementing engineering design tasks in such settings may include a lack of time, as well as a lack of content knowledge and misconceptions of engineering by educators [1-2]. As a way to support children's knowledge construction and meaning-making of engineering in school settings (or lack thereof), we promote the home environment as another potential learning site. As noted in prior scholarship, the home environment has the potential to support children's identity development as engineers [3], influence young children's school readiness [4], create co-learning experiences of STEM concepts through play [5], and support risk-taking and persistence through failure moments [6].

In this exploratory study, we examined the following research question: How do children and their families participate in epistemic practices of engineers within engineering design tasks in their home environment? In this study, epistemic practices are described as ways that members of a community "propose, communicate, justify, assess, and legitimize knowledge claims" in "socially organized and interactionally accomplished ways" [7, p. 99]. More specifically, we utilized Cunningham and Kelly's [8] 16 epistemic practices of engineering for K-12 education contexts to analyze video data of nine families completing a researcher-developed design task in their home. As noted by Cunningham and Kelly, these 16 epistemic practices of engineering offer families a way to think and learn about engineering through active participation in authentic, ill-structured engineering problems. Results highlighted the diverse ways children engaged in interconnected knowledge-building practices similar to engineers, whether independently or with family involvement. Moreover, the framing of the engineering tasks appeared to elicit different epistemic practices of engineers. Through our analysis, we argue for the inclusion of engineering design tasks in home environments to support children's participation in and learning about engineering.

Theoretical Grounding

Active-based learning (ABL) is grounded in constructivist theories of learning [9-12], and is rooted in the consideration of children as active learners, as opposed to passive recipients of information [12], especially through engaging in practical experiences [13]. Even though there are a variety of ways to define what activity-based learning is, the consensus is that children are *involved* in the learning, by doing and by seeing [14]. In this study, children were actively involved in the knowledge construction and sense-making of engineering through their engagement in engineering design tasks in collaboration with a parent and/or sibling. The strength in using ABL is that it allows the learner more freedom and access to real-world knowledge [11]. It also allows the students to pace themselves, based on their unique abilities and environment [15]. Additionally, hands-on, practical learning allows children to challenge their existing knowledge and preconceptions [10] and enhance their critical thinking and problem-solving abilities [11, 13, 16], often times through collaboration with others.

Methods

In this study, we employed natural observations to address our research question. Natural observations afford researchers to witness natural behaviors, actions, and interactions among individuals in everyday contexts [17]. More specifically, we employed video-based observations due to the ability to examine natural behaviors, actions, and interactions in home environments multiple times [18].

Context

For this study, we collaborated with four nearby rural school districts to engage families with at least one child in grades 2-6 to join our program and research initiative. To aid in this effort, we developed various recruitment materials for the districts to utilize, including SeeSaw announcements, teacher emails, and social media content. Each of these materials featured a video introducing our team and offering an overview of the program. As this study took place during the pandemic, we did not target our recruitment to any one social group. Subsequently, for families that expressed interest, we held Zoom meetings with each family to discuss logistical aspects and acquire both adult consent and child assent.

Between January 2020 and April 2020, families actively engaged in completing 4-6 engineering kits designed by the researcher team within their home settings. These kits were structured to lead families through an engineering design process - research, plan/design, create, test, improve, and communicate. Every kit was equipped with affordable materials like playing cards, felt pieces, hot glue guns, and LED lights, alongside a child-friendly guide and a facilitation guide. The facilitation guide included additional aids such as optional open-ended questions, connections to math and science concepts, and troubleshooting tips. As an example of an engineering kit, families were tasked with 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.

Each family picked and ranked six kits they wanted to complete based on a list of ten kits/engineering tasks (see Table 1). A member of the research team delivered two kits to their home approximately one month apart. More information about the kits, instructional material, recruitment material, and communication with families can be found in our facilitation guide and project website.

Table 1. Overview of 10 kits

Name of Kit	Engineering Task
Animal House	Your task is to design a prototype of an animal house that will help stray animals survive extreme weather conditions common to where you live—rain storms, really hot and really cold temperatures, earthquakes, or tornados.
DIY Grabber	Grabbers are handheld tools that can be used to retrieve items from a distance. Design a prototype of a grabber that can pick up three different objects from at least two feet away without damaging or dropping them.
Delivery Package	You want a way to secretly and safely share objects with your friend who lives next door. You choose to design a prototype that will deliver an object at least 6 feet.
Mint Mobiles	Similar to automotive engineers, your task is to build a prototype to test the effect of different variables to report recommendations to the company. The prototype should travel along a straight path down a ramp and travel as far as possible with a minimum of 8 feet.
Paper Roller Coaster	A local amusement park has asked you to design their next roller coaster. You decide to design a prototype suitable for a marble to travel from the start to the finish. You will use the prototype during your presentation to the local amusement park.
Rain Gauge	The National Weather Service is asking for your help in measuring and reporting the amount of rainfall in your city. Using the provided material, build a rain gauge to measure the amount of liquid precipitation over a set period of time.
Soccer Bot	You have been asked by a popular game company to develop handheld soccer bots for a new indoor game for two players. A soccer bot is a robot that plays soccer. For this game, players score goals by hitting a small ball into the opposing "net".
Toy Hack	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.
Trendy Tennies	You have been asked by a popular shoe company to design a new trendy tennis shoe for the unique needs of their four customers. Pick one of the customers and design a tennis shoe to meet their needs. You decide to use everyday products to construct the tennis shoe prototype.
Watercolor Bot	Design a motorized bot that "paints."

Participants

The participants for this study include nine families from four different school districts located in one county in a state located in the Northeast region of the U.S. Across the nine families, there were 14 children (10 females, 4 males) and nine parents (6 females, 3 males). Table 2 includes demographics regarding family participants. Participant-created pseudonyms were used to maintain anonymity.

Table 2. Participant self-identified demographics

Child	Age	Gender	Ethnicity	Parent	Highest Level of Degree	Self-Described Career
Sam	13	M	White	Sally	Bachelor's + 15	Writer
Jake	11	M				
Annie	11	F	Bi-racial	Angela	Master's	Social Work
Krista	8	F	White	Kate	Master's	School Teacher
Beth	9	F	White	Jake	Bachelor's	Software Engineer
Audrey	9	F	Asian	Samuel	---	Software Engineer
Daniel	7	M				
Eve	10	F	White	Martha	Bachelor's	School Nurse
Ashley	10	F				
Eleanor	10	F	White	Tod	Bachelor's	Software Developer
Helen	11	F	Black	Rachel	Master's	Disability Services
Joy	8	F				
Coral	11	F	White	Cori	Bachelor's	Product Marketing
Charlie	7	M				

Data Source

The data source for this study were videos from each family engaged with the kits, as well as shorter clips where families described and/or reflected on their progress, prototype, and experience. Each family self-recorded and shared videos with the research team through the Sibme app [19]. Furthermore, since families were not obligated to complete six kits and had the freedom to discontinue the research component at any time, the quantity and length of videos differed among families. The number of kits completed by families ranged from one kit to six kits. The length of the videos ranged from 2:40 (minutes:seconds) to 53:58 (minutes:seconds). The average video length was 12:26 (minutes:seconds). Each video was transcribed verbatim by a member of the research team. Non-verbal acts of communication were also included. Transcripts were chunked into social events, marked by shifts in observed behaviors, discussions, and/or situations [20]. We framed these social events as "this event or episode is about…their design plan."

Data Analysis

First, we individually coded each episode per family for one or more of the 16 epistemic practices [6]. Cunningham and Kelly [6] classified the 16 epistemic practices into four broad categories: (a) engineering in social contexts (e.g., consider problems in context, persist in the face of failure); (b) uses of data and evidence to make decisions; (c) tools and strategies for problem solving (e.g., consider materials and their properties); and (d) finding solutions through creativity and innovation (e.g., innovating processes, systems, and objects). As an example of our coding process, the following event from the Soccer Bot kit was coded as envision multiple solutions and consider materials and their properties because Ashley shared why she used binder clips as the "arm" of the soccer bot – stronger - as opposed to cardboard. But this was also done in relationship to two designs, highlighting how she brainstormed several different ways to create her soccer bot.

> Ashley: Okay, so this is my soccer bot. (*displayed bot to camera*) And this is my design. I chose number one (*pointed to design*) 'cause I thought the binder clip would be more powerful than the cardboard on number 2 (*pointed to second design*). They're basically the same thing just one's with a binder clip for the thing that hits the soccer bot- the ball.
>
> Martha: Okay, go ahead and press it.
>
> Ashley: (*pressed button and motor spun*) See how that works. It's really strong (*pointed to binder clip on the motor*) the binder clips.

We met following the analysis of each family to converse on areas of agreement and disagreement, working towards a consensus. Next, we tabulated the frequency to consider how often children and their families participated in epistemic practices of engineers by kits. Lastly, we created a visual for each family per kit to look for patterns [21] in terms of how children and their families utilized the various epistemic engineering practices while engaged with the kits in their home environments. We further considered if patterns were observed within the engineering design process that framed the engineering kits- research, plan/design, create, test, improve, and communicate.

Findings

Results highlighted how children participated in a variety of interlocking or connected epistemic practices both with and without the support of their family. In addition, different tasks seemed to inform participation in different engineering tasks. We will discuss each of these in part, providing examples and images from video clips to support our findings. As a reminder, we utilized participant-created pseudonyms throughout to maintain anonymity.

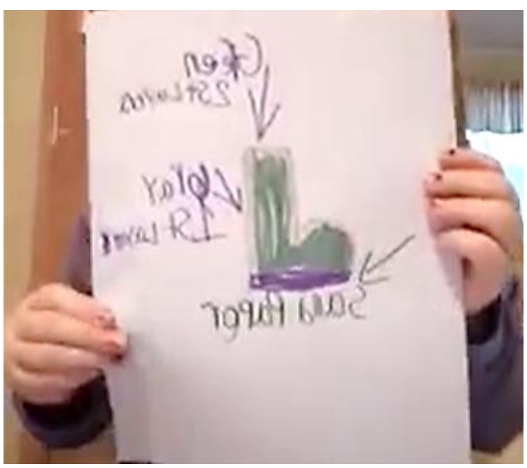
Patterns

First, during the planning process, children and their families engaged in the two epistemic practices – consider materials and their properties and/or consider problems in context – while envisioning one or more solutions. Consider the following information regarding one design solution of trendy tennies (or boots) for Olaf.

> Krista: I decided to do Olaf. (*reading from her notes*) Olaf is a snowman. A best friend to Spen and Kristof. Built out of snow. Lives in Arendelle. (inaudible) on magic snowflakes to fall to make sure he doesn't melt. Purpose, keep feet warm. (*turns paper over*) Shoe design: Sandpaper on the bottom to prevent slipping. Above ankle so snow won't get in the boot. Two layers to keep warm inside. No bright or flashy colors.

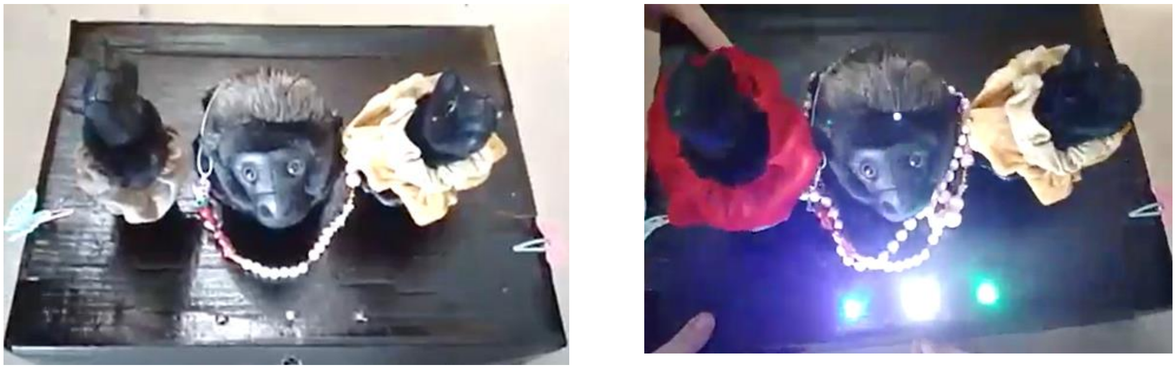
As displayed in Figure 1, Krista brainstormed a design (envision multiple solutions) that was unique to her customer, Olaf. She utilized what she knew about Olaf to inform the design of the shoe (e.g., keep feet warm; consider problems in context). Krista also decided to use material provided in the kit – sandpaper – to prevent Olaf from slipping (consider materials and their properties). While not externally stated, it is assumed that sandpaper was used because of its abrasive layer.

Figure 1. Krista's design solution for a pair of shoes for Olaf



Second, children and their families applied science and math knowledge when developing models and prototypes. In the following example, Eve and Ashley (twins) took an old toy – a stuffed gorilla – and created a new toy – a jewelry and scrunchy holder that would light up (see Figure 2).

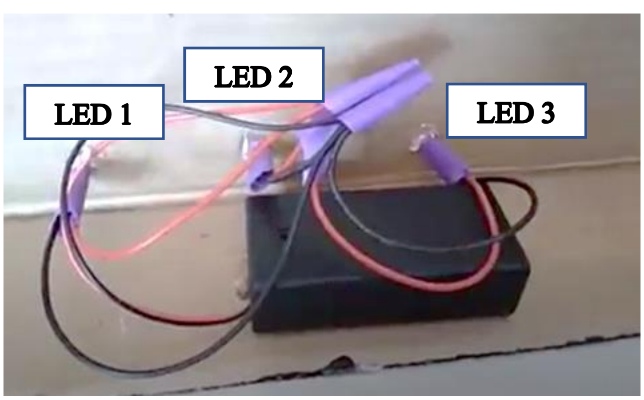
Figure 2. *Eve and Ashley's new toy creation*



As highlighted in the transcript below, they used their knowledge of simple circuits to connect three LED lights to one battery pack using stripped wires.

> Ashley: We added all the red wires together to the battery box so they would all turn on and all the black wires together to the battery box (see Figure 3). And we did all of our electrical stuff like we were supposed to. We added the red to the plus side of the light bulb and the black to the minus side of the light bulb. We also made three holes (*pointed to box where LED were inserted into three holes*) for our three light bulbs that are on the front as you can see here (*turned box so seeing front*).
>
> Eve: We also added glue to the, to the holes (*pointed to one LED with glue*) of the lights because we wanted them (*pointed again to one LED with glue, particularly touched the glue*) to stay in their better. And also we thought it wasn't gonna work because of all the wires had to connect for it to work, but it did, so we're gonna show you it what looks like. (*flipped battery pack from off to on and LED lights worked*).
>
> Ashley: So we got the blue right here (*pointed*), the white (*pointed*) in the middle, and the green right here (*pointed*). And that's our lights.

Figure 3. *Simple circuit for the new toy to light up. This image is the backside of the new toy.*



Ashley and Eve recognized that all the positive (i.e., red) wires and all negative (i.e., black) wires from the three LED lights had to be securely connected to the battery for the lights to work. As illustrated in the figure, they used electrical tape to secure the connection.

Third, children continued to develop and refine their prototype through the act of testing-making evidence-based decisions-persisting in the face of failure. To exemplify, Eleanor (child) and Tod (parent) was tasked with the following: “The automobile company, Rolls-Royce, has produced many cars that are considered of poor fuel efficiency by the United States Department of Energy. Similar to automotive engineers, your task is to build a prototype to test the effect of different variables to report recommendations to the company. The prototype should travel along a straight path down a ramp and travel as far as possible with a minimum of 8 feet.” Eleanor’s first set of tests were failures her mint mobile did not make it down the ramp “to the eight-foot line and it kept on turning [as opposed to going straight].” The body of Eleanor’s first design was constructed using an index card, straws, mints as wheels, and popsicle sticks as a spoiler (see Figure 4-A). Through reflecting upon the failure of the mint mobile to meet the goal of the engineering task, Eleanor constructed a new mint mobile prototype based on the evidence she gathered from her observations (see Figure 4-B). “It won't be able to turn *(moved the car forward on table, and slightly turned it to the left)* unless someone turns it. *(physically turned/pushed the car to the left;* see Figure 4-C*)* And it's way more firm *(pushed down on popsicle stick with finger;* see Figure 4-D*)* and strong *(touched front toothpick and from mint/wheel*).”

Figure 4. *Eleanor’s first and second prototypes*

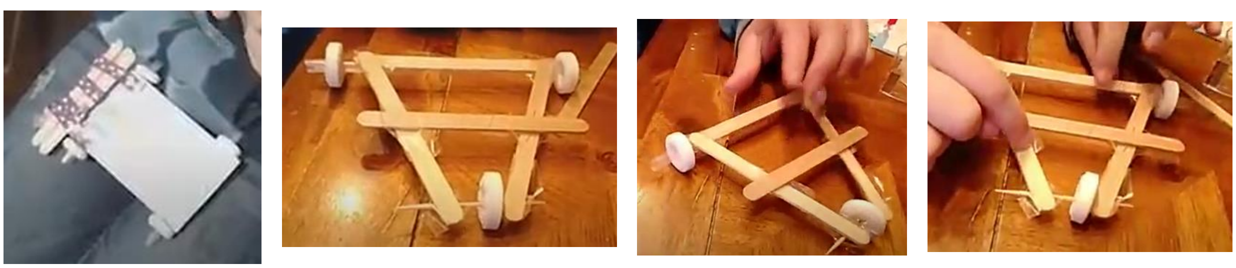


Figure 4-A Figure 4-B Figure 4-C Figure 4-D

In this instance, Eleanor highlighted changes made to the new design through pushing down on the popsicle stick to show it is firm and strong or moving the car on the table to show that it won't turn unless someone turns it. As such, the second prototype was created to address problems observed in testing the first prototype and was deemed successful as the mint mobile traveled more than 8 feet.

<u>Frequency</u>

As noted above, the design of the kits and engineering tasks seemed to elicit specific engineering epistemic practices more than other kits and engineering tasks. First, we observed and coded 28 episodes (56% of all episodes) in which children and families engaged in the epistemic practice, consider problems in context, when designing a new trendy tennis shoe (i.e., Trendy Tennies kit) to meet the unique needs of a customer. We hypothesize this is due to the nature of the task (i.e., customer), as well as children's familiarity with different types of shoes and their purposes (e.g., rain boots). We highlighted one example of this above in which Krista designed a shoe for Olaf. As another instance, Sam and Jake created a prototype for the Hulk/Bruce Banner. The shoe was designed to accommodate both Bruce's shoe size, as well as the Hulk's shoe size. As illustrated in Figure 5, the top part of the sole of the shoe would fold under to fit the foot size of Bruce Banner and fold out to fit the foot size of the Hulk.

Figure 5. *Transformation from Bruce Banner's shoe on the left to the Hulk's shoe on the right*

Second, children and their families envisioned multiple design solutions (15 episodes; 24% of all episodes) when thinking through how to design a prototype for a grabber that would pick up three different objects from at least two feet away without damaging or dropping them. While every kit encouraged children to plan and sketch at least two possible designs, we conjecture that this epistemic practice was more common in the Grabber kit as children would often refer back to their original designs when experiencing moments of failure. The following example is from Beth (child) and Jake (parent). Beth's envisioned three design solutions, each with their own purposes, as stated below and as illustrated in Figure 6.

> I have my three designs. The first one is this one. It's like more of a flip grabbing thing. It grabs things that has like a handle or (*picks up a few rubber bands*) something, like make a little rubber band or a hair band (*picked up a hair tie*) or maybe even a binder clip (*picked up binder clip*). And my second design is more of a scooping (*acted as if scooping with one hand*) kind of thing. And this is (*picked up a toy from table*) pretty similar to it. It's my own grabber that I already have. And it grabs loose things like maybe (*grabs brass fasteners from table using toy*) like some large fasteners.

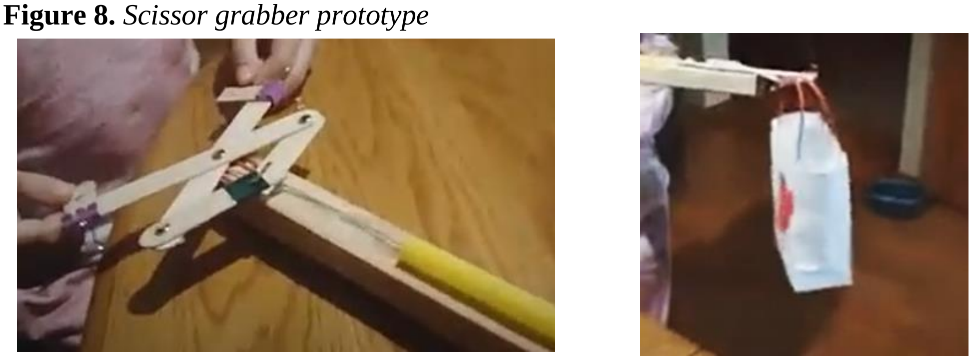
Figure 6. *Beth's three design solutions for the grabber.*

Beth's first prototype was the second design, the scooper (see Figure 7).

Figure 7. *Scooper grabber prototype*

Beth was unable to grab items (e.g., water bottle) with the scooper well. As stated by Beth, "it does have some problems." She went on to explain the problem was "with the rubber bands and they were too stretchy. And too thick." As a family, they made the decision to pick a different design, in which Beth continued to refer to her sketch. "Instead of having to pull the grabber, we decided to pick a different design. So the design we decided to do (*points to sketch*) was the first one as like a scissor grabber type thing, like pinchers I guess." See Figure 8 for an image of the second prototype. As stated by Beth, "Actually it does work a lot better." She was able to pick up a bag, an empty plastic bottle, a clipper, and a roll of tape.

Figure 8. *Scissor grabber prototype*



Third, we observed and coded 9 episodes (35% of all coded episodes) as applying science knowledge when creating a rain gauge that would light up when a certain amount of rainfall accumulated (e.g., 1 inch = blue light, 2 inches = green light, etc.). In the following example, Joy, Helen (children), and Rachel (parent) are exploring which LED leg is positive and which LED leg is negative. This foundational knowledge is crucial to creating a functional rain gauge. The transcript follows Rachel reading the instructions; “the legs of the LED lights are different. Which one is positive and which one is negative? And how do you know? I don’t.” Joy noticed that one leg of an LED light is longer than the other.

> Rachel: Is it the longer that’s negative or the shorter one? I wonder if we could use the, you know how you used the light last night to connect it (*picked up alligator clip)* with the…
> Helen: Yeah. You can test it out by, since this (*picked up battery pack with 2 batteries inserted*), since this...the red is positive (*points to red wire)* and the black is negative (*points to black wire*). We can in a way test it out. (*picked up an alligator clip)*
> Rachel: Test it out. Use the battery to test it out.
> Helen: (*connects alligator clip to black wire*).
> Rachel: Do you have a conductor? Or do you not need a conductor?
> Helen: (*connects another alligator clip to red wire, then connects both wires to LED light*)
> Rachel: Oh, it flickered.
> Joy: Yeah because it touched it.
> Helen: The light is orange.
> Rachel: But what tells you what is negative and what is...? Try it on the other side.
> Joy: (*switched alligator clips*) So nothing good.
> Helen: So it looks like the shorter one is the negative. And the longer one is positive.

As noted in two of the statements by Rachel, we surmise that the family also explored conductive and non-conductive material the previous night. As included in the instructions, families were encouraged to find and test materials around their home that could be used as conductive material for a simple circuit. Helen applied her knowledge of the positive and negative wires and the flow of electrical charge or current to determine appropriately that the shorter leg was negative and the longer leg was positive.

We also observed and coded 9 episodes (and additional 35% of all videos coded) for applying science knowledge as part of the Toy Hack kit. This was likely due to the engineering task, which asked children and their families to give an old toy a second life using electronic parts (see Figure 3 above as an example). The epistemic practice of applying science knowledge was grounded in concepts of current electricity that were embedded within particular kits. Additional MAKEngineering kits where this would apply are in the creation of water color bots or bots that would paint water color art pieces (see Figure 9-A), as well as soccer bots or bots that would hit a ping-pong ball into a net (see Figure 9-B).

Figure 9. Examples of water color bots and a soccer bot on a playing field.

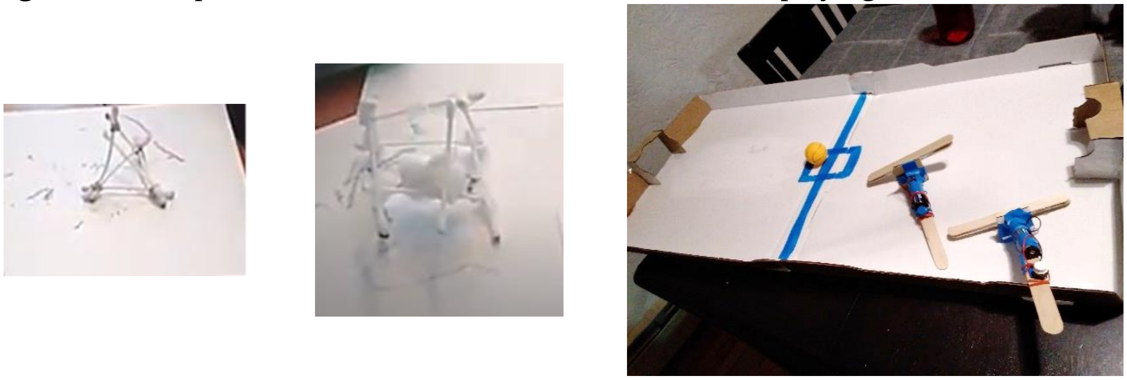


Figure 9-A Figure 9-B

Fourth, we observed and coded 6 episodes (27% of all coded episodes) as system thinking as children often described the components of a simple circuit when creating a soccer bot. Similarly, we observed and coded 6 episodes (27% of all coded episodes) as system thinking when creating a rain gauge. Again, the epistemic practice of systems thinking seemed to more prevalent in kits that included the application of circuitry concepts. Consider the following conversation between Annie (child) and Angela (parent) as they reflect upon the creation of two soccer bots.

> Angela: So if you had to explain to a 6 year old how that worked, what would you say? What was giving the motor the energy to move?
> Annie: I would say that the battery here *(pointed to battery pack)* (see Figure 10-A) is connected (*pointed to motor)* to the motor. And when you press *(moved finger up and down on table)* a button, it gives electricity *(pointed to battery pack to the motor)* to the motor (see Figure 10-B).
> Angela: The button is that white thing?
> Annie: Yes. It connects *(pushed button down)* it so it works. (see Figure 10-C)

Figure 10. *Annie's explanation as to how the soccer bot worked.*

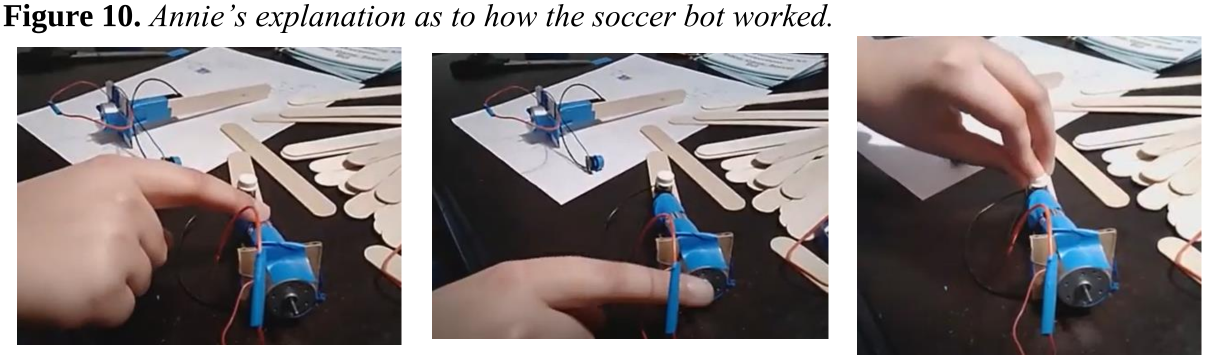


Figure 10-A Figure 10-B Figure 10-C

As such, a six-year-old would gain a foundational understanding of not only the parts (e.g., motor) but how when you push the white button, it would create a closed circuit between the battery and the motor so that the motor (or arm of the soccer bot) would spin to hit a ping-pong ball.

Discussion

In this study, we examined epistemic practices of engineers of children and their families through completing engineering design tasks in their home environment. Through our analysis, we observed patterns in which children engaged in more than one epistemic practice. These highlighted specific instances of overlaps within and across the four categories - (a) engineering in social contexts; (b) uses of data and evidence to make decisions; (c) tools and strategies for problem solving; and (d) finding solutions through creativity and innovation - which Cunningham and Kelly [8] broadly commented as not being mutually exclusive. Our results support this. For example, we observed episodes in which children and their families considered the needs of their clients and/or the materials that might be used for the prototype based on their properties when brainstorming one or more solutions to solve engineering tasks.

Further, we observed a cyclical relationship when children experiences failures when testing their prototype. Through observations, they made and implemented informed-based decisions; thus, children persisted in the face of failure through making changes to their prototype or starting a new prototype. As noted by Crismond and Adams [22] and Johnston et al. [23], children's ability to make sense of what happened (i.e., attend), why it happened, (i.e., interpret), and what changes to make based on "evidence" gathered from their failure experience is a difficult and unnatural process for children who are beginning designers. As such, studies show that students as young as kindergarten are capable of making design decisions [23-24]. Evidence of their decisions are likely informed by personal experiences, external authorities (e.g., teacher), observations from failed tests, and brainstorming solutions with their peers [25-28] as opposed to science and math concepts and principles, criteria and constraints of the problem and available materials, and factors related to customers and context [27].

Additionally, engineering design tasks afford children and their family opportunities to draw upon and apply math and science principles and concepts when creating their prototypes [29]. This highlights how disciplines within STEM intersect and inform one another to support ways of knowing through grounding children's experiences within engineering design tasks. As described by Vazquez [30], this approach to STEM education, defined a transdisciplinary STEM education, is one of the hardest to achieve. In this paper, our emphasis was children's creation of a prototype using their knowledge of simple circuits and conductive material. This was prevalent as the concept of current electricity was a focus of four of our kits at the time of this study. As families engaged in more than one of these MAKEngineering kits, they likely gained familiarity and developed fluency in applying science knowledge, particularly concepts of current electricity, in the development of prototypes. And while we did not discuss the application of math concepts in this paper, our prior research has highlighted children's use of co-variation reasoning [31], spatial reasoning, computation (e.g., average height), and scale factor [32].

The significance of this study not only lies in the potential to engage young children (and parents) in the knowledge construction and sense-making of engineering similar to that of professionals in the field (i.e., epistemic practices), it can inform the design of engineering tasks to support the development of children's epistemic practices in engineering within out-of-school contexts. As the results of this study highlight, the framing of the task itself seems to elicit different epistemic practices. For example, tasks that included a character or a client (e.g., Trendy Tennie), or even a task of interest and/or familiar (e.g., Animal House), children are more likely to engage in the epistemic practice, consider problems in context. This supports prior research that has shown empathy to be a skilled developed through user-centered engineering contexts [33-34]. Similar, the structure and open-ended nature of the kits to align with an engineering design process elicited engagement in particular epistemic practices such as envisioning multiple solutions. In the context of this study, envisioning multiple solutions were grounded in the process of sketching which has been shown to promote the development of innovative ideas, building upon ideas, and deeper thinking about their solutions [35]. Second, the inclusion of familiar and everyday materials (e.g., q-tips, cotton balls, sandpaper, straws) supported children in considering materials and their prototypes within the context of the engineering design tasks. As such, children often rely on everyday experiences and perceptually accessible properties such as thickness, color, weight, and texture for their choice of materials [36-37]. Third, providing opportunities to explore and experiment with how to address the engineering task encouraged children to engage in systems thinking [38-39]. In this study, this was observed more within the concept of circuitry and how the individual parts of a simple circuit should be connected to create a functional prototype.

Conclusion and Future Work

We recognize the limitations of this study to include the limited nature of the videos as they were often recorded in short clips shared by families as opposed to a continuous recording of their interactions. Our analysis also did not account for length of time and the frequency of epistemic practices of engineering were informed by the kits completed, which were not the same across families. However, future research can build upon these results in considering the home environment as a place to support the development and awareness of epistemic practices of engineering among children. How did parents, caregivers, and/or siblings inform and/or hinder children's engagement in the epistemic practices? How might the home environment and engagement with family members position children as active agents in knowledge construction within engineering? How might these practices in the home be associated with other constructs such as children's interest in engineering [40]? Another line of research may build upon similar studies of engaging children in epistemic practices in the field of science [41-42]. Studies have shown positive effects of argumentation, exploration and inquiry-based science instruction on the frequency and variety of children's epistemic practices [43-44]. We also observed few instances of the epistemic practices making trade-offs between criteria and constraints, assessing the implications of solutions in the real world, and innovating processes, methods, and designs. The question of why this was the case may be embedded in the design and structure of the kits. A design-based research approach [45] with families and educators may serve as a useful approach. Lastly, while participants in this study spanned grade levels, gender, and ethnic social groups, future research may expand upon this sample to include a broader spectrum of demographic backgrounds.

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References

[1] E. R. Banilower, P. S. Smith, K. A. Malzahn, C. L. Plumley, E. M. Gordon, and M. L. Hayes, *Report of the 2018 NSSME+*, Horizon Research Inc., 2018.

[2] E. J. Kang, C. Donovan, and M. J. McCarthy, "Exploring elementary teachers' pedagogical content knowledge and confidence in implementing the NGSS science and engineering practices," *Journal of Science Teacher Education,* vol. 29, pp. 9-29, 2018.

[3] A. Simpson and P. N. Knox, "Children's engineering identity development within an at-home engineering program during COVID-19," *Journal of Pre-College Engineering Education Research (J-PEER),* vol. 12, Article 12, 2022.

[4] S. Alexandre, Y. Xu, M. Washington-Nortey, and C. Chen. "Informal STEM learning for young children: a systematic literature review," *International Journal of Environmental Research and Public Health,* vol 19, Article 8299, 2022.

[5] J. Backman and L Dierking, "Co-creating playful environments that support children's science and mathematics learning as cultural activity: Insights from home-educating families," *Children, Youth and Environments,* vol. 21, pp. 294-311, 2011.

[6] P. N. Knox, A. Simpson, and A. V. Maltese, "Fortitude in frustration and failure: Exploring emotional responses within an at-home elementary engineering program," *American Society for Engineering Education Ann. Conf. & Exp*, Baltimore, MD, 2023.

[7] G. J. Kelly, "Inquiry, activity, and epistemic practice," in *Teaching Scientific Inquiry: Recommendations for Research and Implementation,* R. Duschl and R. Grandy, Eds. Rotterdam, The Netherlands: Sense Publishers, 2008, pp. 99-117.

[8] C. M. Cunningham and G. J. Kelly, "Epistemic practices of engineering for education," *Science Education,* vol. 101, pp. 486-505, 2017.

[9] S. Bhan, "Activity based learning in commerce and tourism education," *African Journal of Hospitality, Tourism and Leisure,* vol. 3, Article 31, 2014

[10] S. Hussain, S. Anwar, and M. I. Majoka, "Effect of peer group activity-based learning on students' academic achievement in physics at secondary level," *International Journal of Academic Research,* vol. 3, pp. 940-944, 2011.

[11] C. Ma, R. Xiao, Y. Wei, and H. H. Yang, "An inquiry-based learning approach on a educational technology course," *Proceedings of the 2011 IEEE International Symposium on IT in Medicine and Education (ITME),* vol. 1, pp. 422-424, 2011.

[12] B. V. V. Padmavathi, "Activity based learning," *Research Journal of English Langauge and Literature,* vol. 1, pp. 287-289, 2013.

[13] S. Moeed, "Activity based learning and development of high mental abilities an intention of intermediate level chemistry syllabus," *International Journal of Theory and Application in Elementary and Secondary School Education (IJTAESE),* vol. 1, pp. 131-144, 2019.

[14] M. N. Suydam and J. L. Higgins, *Activity-based learning in elementary school mathematics: recommendations from research,* National Institute of Education, 1977.

[15] M. Tsai, P. Shen, W. Chen, L. C. Hsu, and C. Tsai, "Exploring the effects of web-mediatd activity-based learning and meaningful learning on improving students' learning effects, learning engagement, and academic motivation," *Universal Access in the Information Society,* vol. 19, pp. 783-798, 2019.

[16] P. Thaiposri and P. Wannapiroon, "Enhancing students' critical thinking skills through teaching and learning by inquiry-based learning activities using social network and cloud computing, *Procedia – Social and Behavioral Science,* vol. 174, pp. 2137-2144, 2015.

[17] F. Gardner, "Methodological issues in the direct observation of parent-child interaction: Do observational findings reflect the natural behavior of participants?," *Clinical Child and Family Psychology Review,* vol. 22, pp. 185-198, 2000.

[18] C. Zahn, A. Ruf, and R. Goldman, "Video data collection and video analyses in CSCL research," in *International handbook of computer-supported collaborative learning,* U. Cress, C. Rose, A. Friend Wise, and J. Oshima, Eds., Springer, 2021, pp. 643-660.

[19] Sibme, "Sibme," www.sibme.com/, 2023.

[20] A. W. Harrist, J. A. Achacoso, A. John, G. S. Pettit, J. E. Bates, and K. A. Dodge, "Reciporcal and complementary sibling interactions: Relations with socialization outcomes in the kindergarten classroom," *Early Education and Development,* vol. 25, pp. 202-222, 2014.

[21] J. Saldaña, *The coding manual for qualitative researchers,* Sage, 2012.

[22] D. P. Crismond and R. S Adams, "The informed design teaching and learning matrix," *Journal of Engineering Education,* vol. 101, pp. 738-797, 2012.

[23] A. C. Johnston, R. D. Lopez-Parra, K. M. Tank, T. J. Moore, and B. Fagundes, "Design decision processes of first grade students during an engineering design-based STEM unit," *American Society for Engineering Education Ann. Conf. & Exp.,* Tampa, FL, 2019.

[24] A. M. Rynearson, T. J. Moore, K. M. Tank, and E. Gajdzik, "Evidence-based reaonng in a kindergarten classroom through an integratd STEM curriculum, *American Society for Engineering Education Ann. Conf. & Exp.*, Minneapolis, MN, 2022.

[25] V. Cappelle, L. G. Franco, and D. Munford, "Use of drawings and connections between epistemic practices in grade 1 science lessons," *Science & Education*, 2023.

[26] K. A. Douglas, T. J. Moore, A. C. Johnston, and H. E. Merzdorf, "Informed designers? Students' reflections on their engineering design process," *International Journal of Education in Mathematics, Science, and Technology,* vol. 6, pp. 443-459, 2018.

[27] C. A. Mathis, E. A. Siverling, A. W. Glancy, S. S. Guzey, and T. J. Moore, "Students' use of evidence-based reasoning in K-12 engineering: A case study," *American Society for Engineering Education Ann. Conf. & Exp.*, New Orleans, LA, 2016.

[28] K. B. Wendell, C. G. Wright, and P. C. Paugh, "Urban elementary school students' reflective decision-making during engineering learning experiences," *American Society for Engineering Education Ann. Conf. & Exp.*, Seattle, WA, 2015.

[29] E. A. Siverling. E. Suzao-Flores, C. A. Mathis, and T. J. Moore, "Students' use of STEM content in design justifications during engineering design-based STEM integration," *School Science and Mathematics*, vol. 119, pp. 457-474, 2019.

[30] J. Vazquez, "STEM-Beyond the acronym," *Educational Leadership,* vol. 72, pp. 10-15, 2014.

[31] A. Simpson, J. Kim, and J. Yang, "Caregiver-child interactions: Informal ways of doing mathematics during engineering tasks," *North American Chapter of the International Group for the Psychology of Mathematics Education*, Philadelphia, PA, 2021.

[32] A. Simpson, J. Kim, and J. Yang, "Caregiver-child communication of STEM concepts with engineering design tasks," *American Society for Engineering Education Ann. Conf. & Exp*., Minneapolis, MN, 2022.

[33] S. Letourneau and D. Bennett, "Using narratives to evoke empathy and support girls' engagement in engineering, *Connected Science Learning*, vol. 3, 2020.

[34] P. S. Lottero-Perdue and J. Settlage, "Eqitizing engineering education by valuing children's assets: Including empathy and an ethic of care when considering trad-offs after design failures," *Journal of Pre-College Engineering Education Research*, vol. 11, Article 4, 2021.

[35] E. Shokeen, "Understanding learning and sketching experiences of children involved in STEM design," Ph.D dissertation, College of Information Studies, University of Maryland – College Park, 2023.

[36] C. L. Smith, "Bootstrapping processes in the development of students' commonsense matter theories: using analogical mappings, thought experiments, and learning to measure to promote conceptual restructuring," *Cognition and Instruction,* vol. 25, pp. 337-398, 2007.

[37] K. B. Wendell and H.-S. Lee, "Elementary students' learning of materials science practices through instruction based on engineering design tasks," *Journal of Science Education and Technology,* vol. 19, pp. 580-601, 2010.

[38] S. Huang, K. H. Muci-Kuchler, M. D. Bedillion, M. D. Ellingsen, and C. M. Degen, "Systems thinking skills of undergraduate engineering students," *IEEE Frontiers in Education conference,* El Paso, TX, 2015.

[39] C. N. Lippard, M. H. Lamm, K. M. Tank, and J. Y. Choi, "Pre-engineering thinking and the engineering habits of mind in preschool classroom," *Early Childhood Education Journal,* vol. 47, pp. 187-198, 2019.

[40] S. Pattison, G. Svarovsky, and S. Ramos-Montañez, "Understanding early childhood engineering interest development as a family-level systems phenomenon: Findings from the Head Start on engineering project," *Journal of Pre-College Engineering Education Research,* vol. 10, Article 6, 2020.

[41] G. J. Kelly and P. Licona, "Epistemic practices and science education," in *History, philosophy and science teaching: New perspectives*, M. R. Matthews, Ed., Springer, 2018, pp. 139-165.

[42] W. A. Sandoval, "Understanding students' practical epistemologies and their influence on learning through inquiry," *Science Education,* vol. 89, pp. 634-656, 2005.

[43] Y.-C. Chen, B. Hand, and S. Park, "Examining elementary students' development of oral and written argumentation practices through argument-based inquiry," *Science & Education,* vol. 25, pp. 277-320, 2016.

[44] J. Rios, S. P. Xana, and J. B. Lopes, "From stories to science: An exploration guide to promote epistemic practices in primary school, *International Conference on Technology and Innovation in Learning, Teaching and Education*, Springer Nature Switzerland, pp. 157-170, 2022.

[45] A. Minichiello and L. Caldwell, "A narrative review of design-based research in engineering education: Opportunities and challenges," *Studies in Engineering Education*, vol. 1, pp. 31-54, 2021.