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A Study of Problem Exploration Heuristics of Families (Fundamental)

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Abstract

To meet the demands of science and engineering practices in K-12 education, elementary students are often engaged in well-defined problems as opposed to ill-defined authentic problems and puzzling phenomena that mirror the work of professional engineers. In our research, we consider the home environment as an alternative route to engage elementary-aged students in authentic engineering problems that are grounded in familial and cultural contexts and assets. The purpose of this study is to add to the growing body of knowledge of the use of heuristics in the identification of engineering problems and brainstorming of solutions that are relevant and applicable to young children. By examining the various problem exploration heuristics families utilized when identifying and exploring authentic problems in their home environment, more is learned about ways families and home environments can be leveraged to engage young children in engineering practices and design thinking.

Introduction

Research has shown that within the context of engineering education, the design stages of problem exploration and identification, as well as the brainstorming of multiple solutions, are key practices in design and design thinking [1], [2] and support the development of creative activities and processes [3], [4]. In the context of K-12 schooling, problem identification and solution ideation are informed by the Next Generation Science and Engineering Standards [5] as children should be provided opportunities to define and describe problems that can be solved, specify and consider constraints and criteria, generate multiple solutions, and communicate design ideas and/or solutions. Elementary students are often engaged in well-defined problems as opposed to ill-defined authentic problems and puzzling phenomena that mirror the work of professional engineers [6], [7]. In addition, research has illustrated how teachers may struggle with facilitating open-ended design challenges in their classrooms as this approach is unfamiliar, and often uncomfortable [8], [9]. Elementary teachers must also overcome barriers such as the demands of standards and high-stakes testing in reading and mathematics and lack of administration support [10], [11].

With the ongoing struggles and tension that exists within the school environment, we considered an alternative environment in this study – the home. Our intent was to focus on the complex and nuanced strategies families employed when developing and generating problems and solutions grounded in the engineering design process (i.e., problem exploration heuristics; [12]). This is often not explored with elementary-aged students, but has the potential to uncover and understand children’s abilities to engage in problem-scoping practices similar to experts in the field [13]. In particular, we address the following question: What heuristics do families utilize when identifying and exploring authentic problems in their home environment through an engineering design perspective? Heuristics, in this study, are defined as specific methods or strategies used to generate a judgement or decision specific to problem identification and potential solutions [14], [15]. We contend that this research addresses the recent call from the Committee on Enhancing Science and Engineering in Prekindergarten through Fifth Grade [16] to conduct more research on understanding how families engage as engineers through their local ways of knowing and sense making of their natural environment. As we illustrate, families utilized three common heuristic patterns: (a) person-centric, (b) material-based, and (c) place-based. The results of this study have implications for how program developers and practitioners engage children and their families in engineering practices and design processes. These are detailed at the conclusion of this paper.

As research regarding children's problem exploration heuristics is limited, we include relevant scholarship that highlights the development and implementation of engineering instruction in elementary classroom settings with a focus on the problem and planning stages of an engineering design process. As such, when provided with support (e.g., professional development), teachers are able to plan engineering lessons that frame the problem development phase – identification of goals, clients, criteria and constraints, and background knowledge - and encourage the development of multiple solutions [7]. During these two stages (i.e., problem scoping and exploration), children have been observed exploring different perspectives of the problem, engaging in reflective decision making, developing an optimal solution [13], [17], [18]. These researchers argued for acknowledging children's abilities to engage in heuristic practices common to expert designers and engineers.

We contend, as do others, that parents serve as an additional resource of knowledge within the larger STEM ecosystem, and that the uniqueness of parent–child interactions lies in their ability to build on their children's abilities, experiences, and prior knowledge, as well as include shared experiences such as visits to an aquarium [19]-[22]. As such, research has consistently shown how parent-child interactions and conversations in out-of-school contexts (e.g., museums, homes, parks) support their children's development, interest, identity, and positive dispositions of STEM concepts and skills [19], [23]-[26]. For example, Acosta et al. [19] observed how parents and children talk about STEM during a Make it Roll exhibit was positively associated with children's STEM talk in their reflections following their engagement in the exhibit. Parents have been observed facilitating these interactions and conversations through various approaches (a) posing open-ended questions such as *How…?* and *Why…?* [20], [23], [27], [28], (b) modeling problem-solving processes [29], (c) supporting children's decision making through positive encouragement [30], (d) shifting epistemic agency to their child(ren) [31], (e) associating present and prior experiences [32], and (f) bridging out-of-school experience with present and future school experiences [33]-[35]. In this study, these approaches are employed towards engaging children in discussions targeted at generating a decision specific to the problem identification and solution ideation.

Methods

This study employed a collective, instrumental case study design [36] to explore and understand a particular situation, the various heuristics that families draw upon when brainstorming and identifying an authentic problem and possible solutions within a natural environment (i.e., home). The inclusion of five families will afford the examination of similarities and differences among the families or cases [36].

<u>Context</u>

The larger study took place in two phases from January 2020 to June 2020. Potential family participants were recruited through posting brief information and a video about the project through school district social media posts, newsletter posts and/or emails from teachers. From January to April, families completed between 4-6 researcher-developed engineering kits in their home environments. Each engineering kit guided families through an engineering design process – identifying a task or problem, research, plan/design, create, test, reiterate, and communicate. Each kit included low-cost materials (e.g., straws, electrical tape, LED lights), a child guide, and a facilitation guide with built in supports such as optional open-ended questions and troubleshooting tips. See our project website at (blinded) for access to the kits and guides. As an example of an engineering problem, families were tasked with the following:

> It is challenging for stray animals to survive extreme weather conditions. 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 cold temperature, earthquakes, or tornados.

The second phase occurred between May to June. During this phase, families were tasked with identifying a problem that was personal to them, namely something in their home, community, school, or for someone they know. The goal was to build upon their engagement and understanding of the engineering design processes from the engineering kits, while also using material from in and/or around their home environments. Families were provided with a self-paced slideshow that included researcher-developed example projects and videos (blinded). Similar to the engineering kits, the slideshow guided families through identifying a problem, brainstorming various solutions, and then designing, testing, and modifying prototypes. Throughout this project, families did not have any contact with researchers with the exception of virtual show-and-tell sessions. As the name implies, the intent of these virtual sessions was for families to communicate aspects of their process and prototype during both phases of the program. The data from the second phase, particularly the identification of the problem and possible solutions, is the focus of this study. The results include each family's self-identified problem.

<u>Participants</u>

The participants for this study include five families from four different school districts located in one county in a state located in the Northeast region of the U.S. Across the five families, there were 8 children (6 girls, 2 boys) and 6 caregivers. At the time of the study, the age/grade of the children ranged from 8-11/Grade 2-6. The families self-identified as Asian (1), Biracial (1), and White (3). Further, as a household, each family earned more than $75,000 a year. The results include detailed information regarding each family. Pseudonyms are used to refer to each family, as well as members of the family.

Data Source

Study data are comprised of self-recorded videos from each family, as well as recordings of two virtual show-and-tells that occurred in phase two. For the self-recorded videos, there were three "share" prompts embedded in the self-paced slideshow that are relevant to this study. They were:

1. As a family, record and share your problem ideas and why each one is a problem. Then discuss and pick ONE problem you would like to design a solution for as a team of engineers.
2. As a family, record and share your brainstorming conversation as it unfolds (i.e., in-the-moment). Then pick ONE design solution.
3. As a family, share your detailed plan(s). Walk us through how you made your decisions and the materials you will use.

Each family recorded and shared their response to these prompts through Sibme, an app that affords an exchange of videos and resources through a secure cloud. The amount of video data shared from each family varied from 1:30 (min:sec) to 39:48.

In addition, each family attended both show-and-tell sessions that lasted between 30-45 minutes in length. These supplemented and/or furthered the examination of problem exploration heuristics provided in the self-recorded videos. During these sessions, families shared their decision-making process regarding their identified problem, solution, design sketches and materials, and in-process prototypes. Families asked one another questions (e.g., "What kind of wood will you use?"), while also providing suggestions (e.g., "I think you can also market your idea to older adults.").

Data Analysis

Analysis of the video data began by using the 42 problem exploration heuristics developed from Studer's [37] research study with undergraduate and graduate mechanical engineering students. This approach aligned with Watkins et al. [13] argument for the importance of understanding the nuances and richness of children's problem scoping in ways that are similar to expert's practices. Through the analysis of self-recorded video data from one family, we determined that the 42 problem exploration heuristics were too many, too specific, and too implausible for our data. As an example, "describe the required manufacturing process and its limitations," is more than likely not within the realm of possibility in a family engineering program. Therefore, we broadened the scope of our analysis through employing and expanding upon the five following heuristics [37] that aligned well with our prompts: (a) Break down the primary need, (b) Define the primary stakeholder, (c) Identify existing solutions, (d) Define the setting, and (e) Describe environmental constraints. As an example of a modification, we applied the heuristic Identify possible solutions as opposed to Identify existing solutions. This encompassed all the solutions families brainstormed to address their self-identified problem. The possibility of additional heuristics beyond these five were also considered throughout the analysis. The different problem exploration heuristics identified in this study are listed in Table 1.

Table 1. Problem Exploration Heuristics

Heuristic	Definition
Break down the Primary Need	Describe reasons or the various needs for the self-identified problem.
Identify the Primary Stakeholders	Identify the individuals or groups that will benefit from addressing the self-identified problem.
Identify Possible Solutions	Brainstorm and communicate potential solutions for addressing the self-identified problem.
Implied or Identified Setting	List different setting in which the prototype can be utilized.
Describe Eco-friendly Criteria	Detail materials and resources to include that are environmentally friendly.
Describe Possible Features	List design features for the identified solution(s).
Describe Affordances	Explain the benefits for selecting the solution or prototype for addressing the self-identified problem.
Identify Size	Specify the expected size of the prototype and/or product.
Describe "Manufacturing" Process	Describe features of the material and resources needed to address the self-identified problem

Results

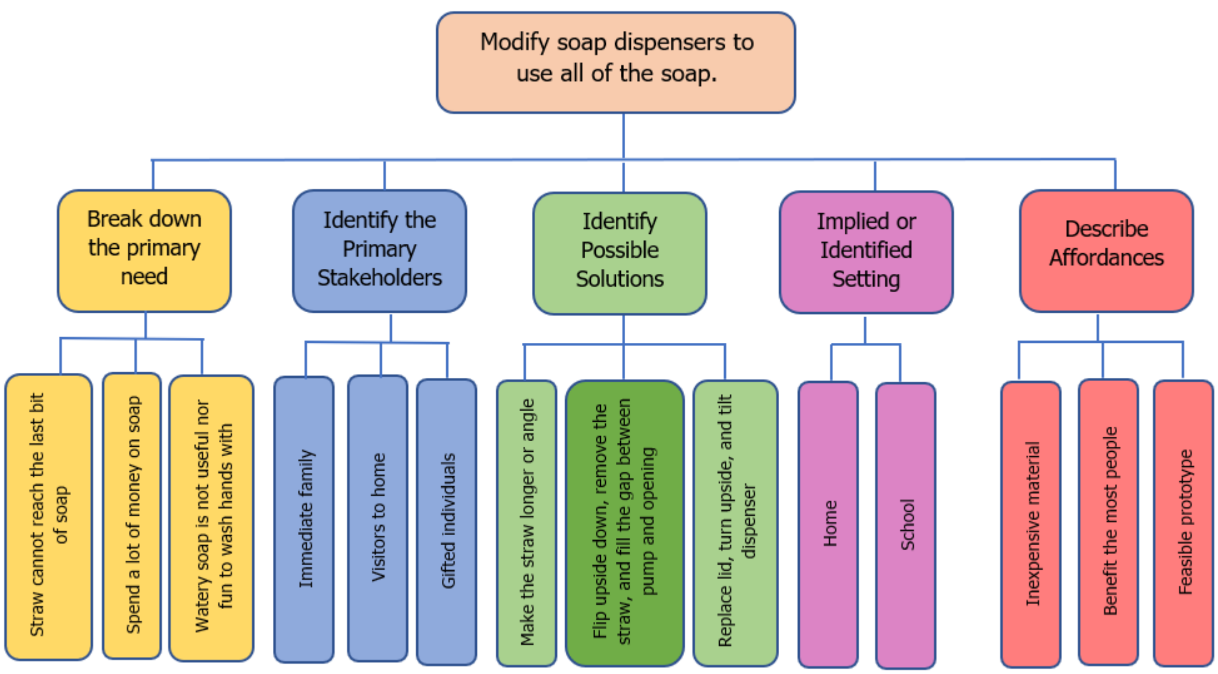
We present each case study below including information about each family and their identified problem. The various heuristics used and specific examples from the data are diagramed for each family. In the discussion, we highlight three predominant heuristic themes that participating families employed when working together to identify a challenge or problem, as well as the number and nature of solution ideas to address them.

<u>Anderson Family – Beth, Eva (Children), Jake, & Sammi (Caregivers)</u>

As expressed by Jake (paternal caregiver) and Sammi (maternal caregiver), the Andersons joined this program to provide opportunities to introduce Beth and Eva to hands-on learning experiences in science, technology, and engineering. While Beth, who was in third grade at the time of the study, thought being a part of the program would be fun. As a household, their income was above the poverty level as Sammi was an attorney and Jake, a software engineer. Although Jake worked in the engineering industry, he expressed in a post-program interview how he did not engage in a lot of hands-on building projects. Being a part of this program afforded him a way to talk about what he does, namely how the process and the prototypes they worked on together are very similar to what he worked on professionally. As stated by Jake, “I can definitely do more- we can talk about that more and show her. When we go to the office, it's not just to play, I can actually show her what I do.”

The Andersons developed several problems before deciding on modifying soap dispensers to use all the soap (see Figure 1). These included (a) creating a “bigger belt hanger for dad,” (b) “build a dolly for the recycling bin,” and (c) “build a shelter for waiting on the [school] bus.” The decision to choose the soap dispenser problem was made through describing the affordances and hindrances of each problem. For example, Sammi asked, “Which one do you think would be the most work?” This eliminated the shelter. Or “which one would benefit the most people?” Beth initially stated the shelter before Sammi encouraged Beth to think beyond the immediate and extended family through asking Beth to think about where she uses soap dispensers – at school (i.e., identified setting). As they began thinking about the prototype, they would pair a primary need with a possible solution. For instance, the Anderson’s noted that “the way it's [straw] designed, it doesn't even reach the bottom of the container. So there's a lot of soap sitting at the bottom.” The solution or modification proposed was to “make the straw longer or angle it so it could reach all of the soap.” Through their discussion, they decided on an upside-down soap dispenser (see dark green in Figure 1).

Figure 1. Diagram of the Anderson’s Problem Exploration Heuristics

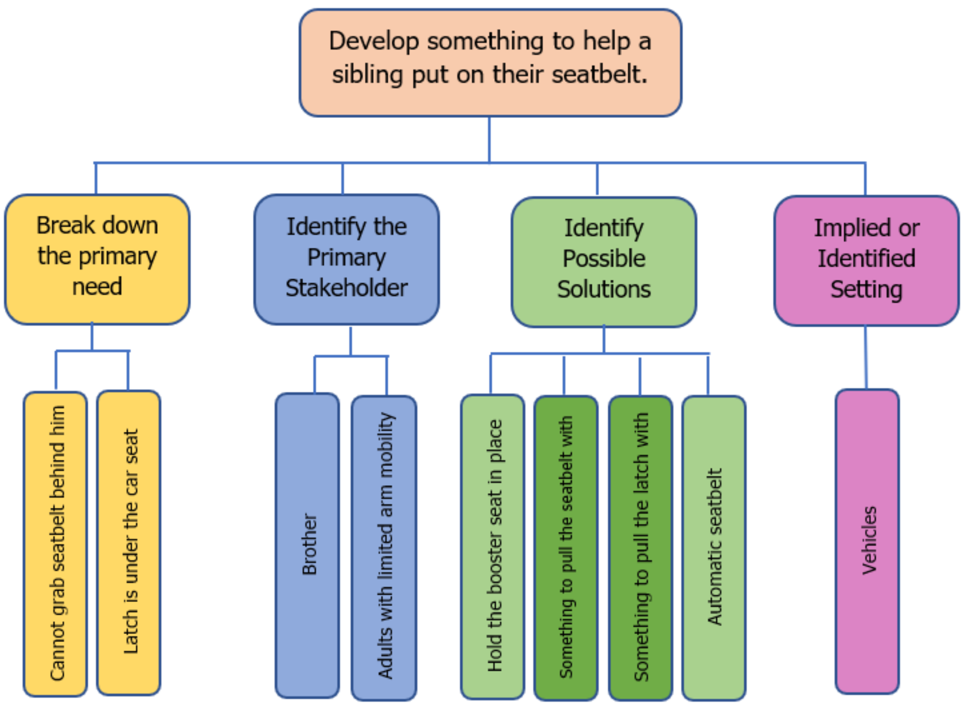


Barton Family – Elizabeth (Child) & Travis (Caregiver)

The Barton's joined the program to expose Elizabeth, a fifth grader at the time of the study, to hands-on engineering experiences. Elizabeth expressed joining as she was interest in learning more about engineering. Travis, the maternal caregiver, was a software engineer, and similar to Jake, noted having a "shared language to talk about what I do."

The Barton family generated three initial problems that were specific to their needs as a family: (a) something to "help my brother put on his seatbelt," (b) an automatic cat feeder, and (c) "something to help my [Elizabeth] piano book from falling while I'm playing piano." As noted in Figure 2, the Barton family ultimately decided to develop a prototype to support their youngest child in putting on his seatbelt for two reasons, namely, he cannot grab the belt and the latch is often under his car seat. In one of the group sessions, the family expanded their thinking around pertinent stakeholders who might benefit from their design to include adults who have limited mobility in their arms.

Figure 2. Diagram of the Barton's Problem Exploration Heuristics



Hand Family – Annie (Child) & Angela (Caregiver)

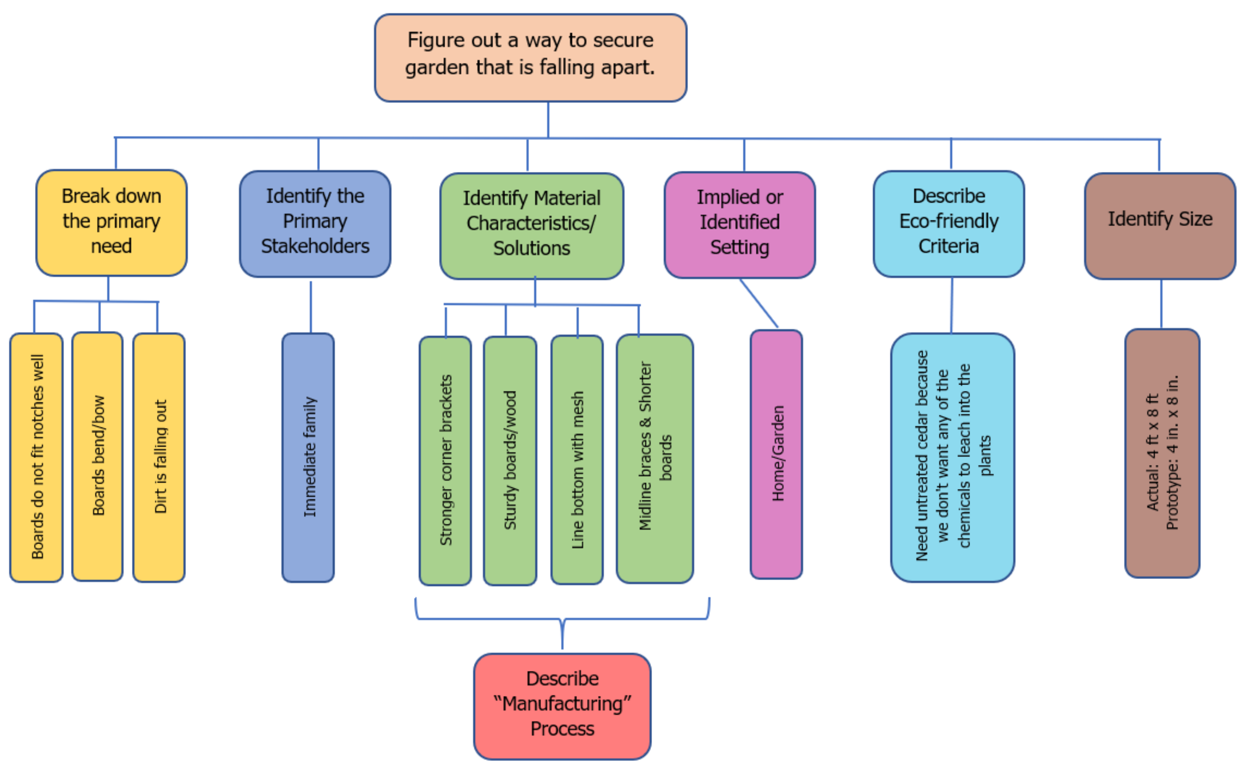
The Hand family was interested in the program because there was little to no local STEM-related activities for a sixth-grade student without a large fee. The program also built upon Annie's general interest in science and curiosity about engineering. By the end of the program, Angela (maternal caregiver) described how they as a family were thinking more like engineers as both caregivers had a career in social work. Angela stated, “I think the one thing it taught us, especially in our house is it's okay to try something and mess up, which I think is a hard lesson to learn.” She provided an example of how they used a measuring tape and discussed how to rearrange their patio furniture to maximize the space as opposed to “put[ting] it all out” and leaving it as is.

The Hand family generated three initial problems before deciding to find a way to support and secure their raised garden/flower bed that was falling apart (see Figure 3). The other two problems identified were a mask that could add an adjustable piece and a way to stop their dog Max from biting his tail. After deciding on the raised garden/flower bed, the brainstorming process was focused more on the type of material needed to replace and support their existing structure (e.g., stronger corner or midline braces, stronger shorter, and untreated wood planks) as opposed to designing something new. Consider the following quote from Annie.

> We could line it [raised garden/flower bed] with this kind of mesh at the bottom so that the dirt doesn't actually fall out, even if there are holes in the garden, which could possibly work. And then we could add actual supports in the boards with notches in them so that they could be more steady and wouldn't bend in the middle, which is where they normally bend. We could get shorter boards between the supports if we were to add supports, and then we could just purchase better materials.

This approach to their existing raised garden/flower bed addressed their primary needs (e.g., dirt failing out, wood boards bend).

Figure 3. Diagram of the Hand’s Problem Exploration Heuristics

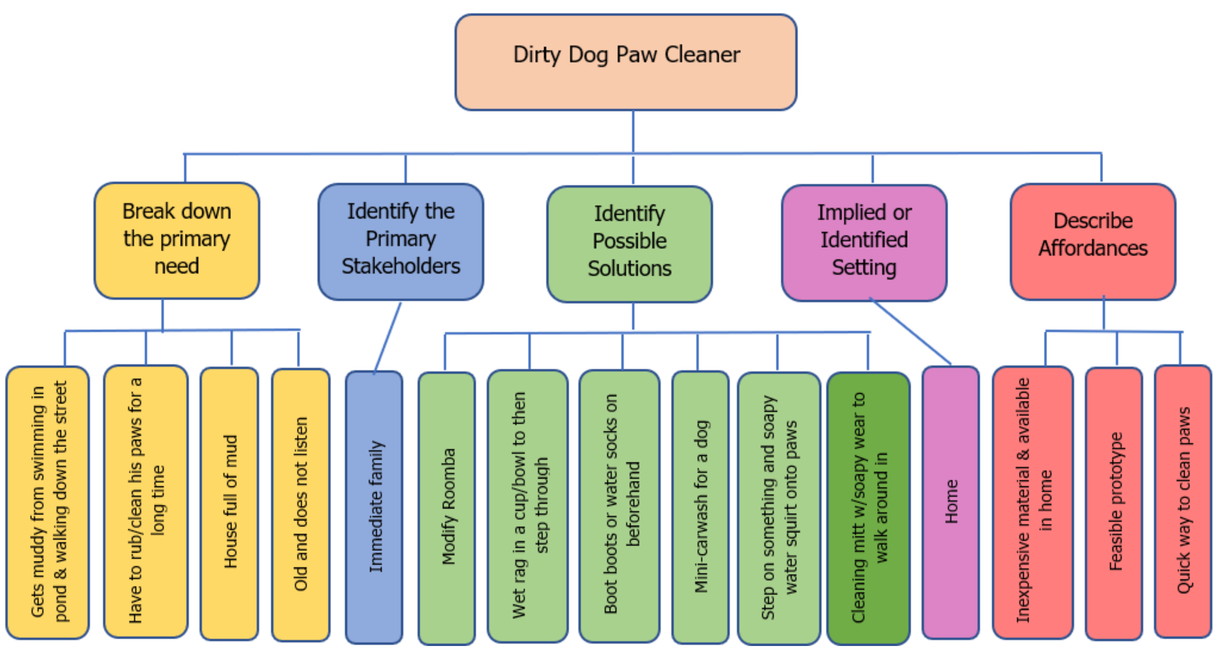


Murphey Family – Cassie, Gabe (Children), & Kim (Caregiver)

Similar to other families, the Murphey family joined to give Cassie and Gabe an opportunity to engage in fun STEM projects. Gabe too noted wanting to do fun projects. Cassie was more interested in learning about different types of engineers as both caregivers received their degrees in a field of engineering – aerospace and electronic system design and manufacturing. Kim expressed how they were not intentional about doing engineering in their home environment, but that this program "forced us to- Now we know a process that they [Cassie and Gabe] can do and apply to things around the home."

The Murphey family decided to focus on a dirty dog paw cleaner (see Figure 4) as their old dog loved to explore their neighborhood and often brought mud into the house (i.e., primary needs). Other problems generated by the Murphey family included (a) "weekend chicken waterer" for when they travel, (b) leaving toys around after they are finished playing, (c) losing remote controls, and (d) prickles, or small thorns, in the lawn. Similar to the Armstrong family, they next focused on the design affordances and constraints including materials that would be needed, cost of materials, if a solution already exists (e.g., prickles), and possibility of creating the prototype in their home environment. As noted in Figure 4, they brainstormed multiple solutions to their self-identified problem. They each argued for their solution, including defending counter arguments, before casting individual votes between 0-5 with the "winner" being the solution with the highest score. In scoring the potential solution – mini carwash – Gabe stated, "I'd rank it a four." Kim agreed, "Okay, I'll give it a four because it might work." Lastly, Cassie casted her vote, "I'll give it a four too."

Figure 4. Diagram of the Murphey's Problem Exploration Heuristics

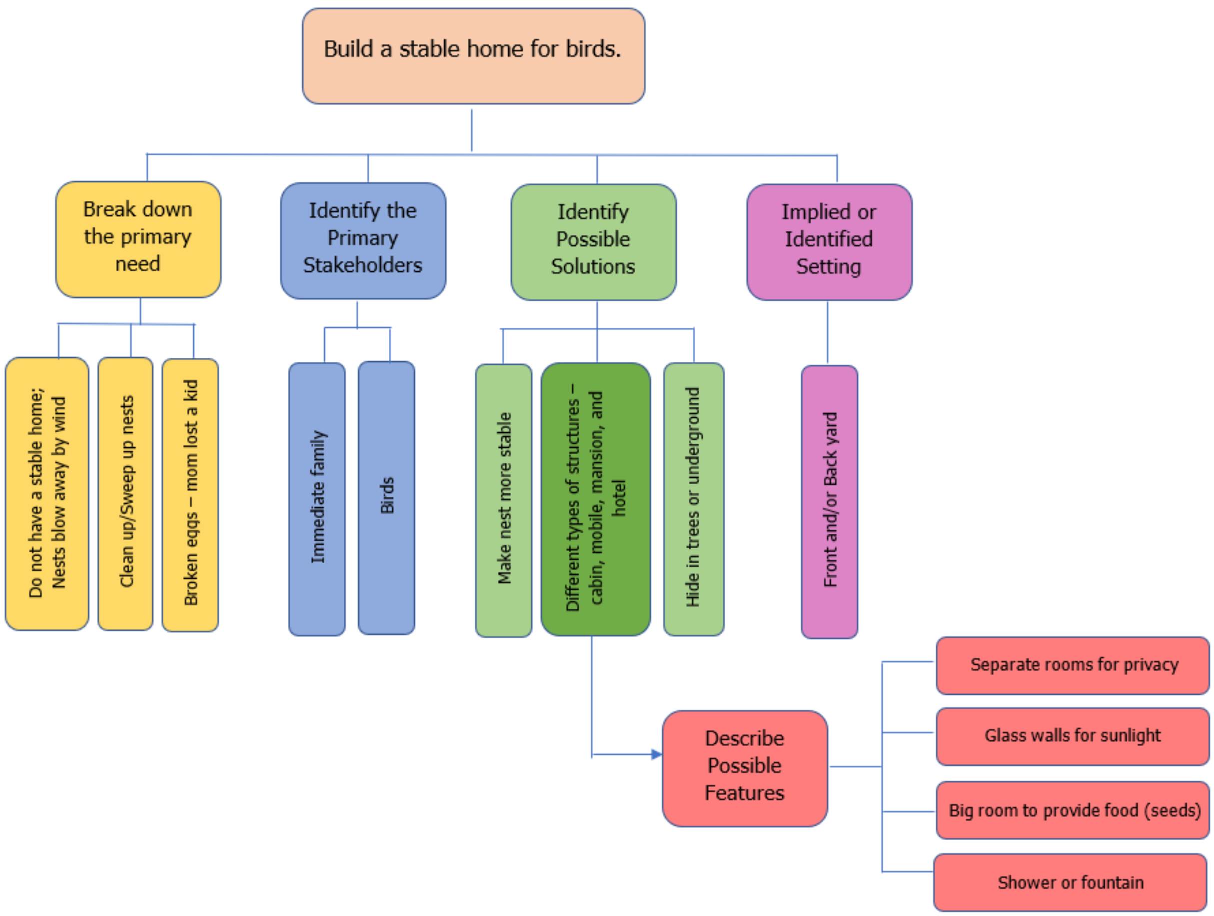


Ying Family – Audrey, Daniel (Children), & Samuel (Caregiver)

Samuel noted how the goal for joining the program was for Audrey and Daniel to experience engineering at an early age, as well as building a family atmosphere. Audrey wanted to do the program as she was interested in fun activities. As a software engineer, Samuel found the program provided a way to talk about engineering and the type of engineering they were doing throughout the program.

Problems identified by the Ying family included (a) birds do not have a stable home, (b) dead tree branches falling in their yard, (c) too many bugs in their home, (d) too much noise during virtual schooling, and (e) YouTube is too distracting that Audrey and Daniel are not able to focus on their homework.

Figure 5. Diagram of the Ying's Problem Exploration Heuristics

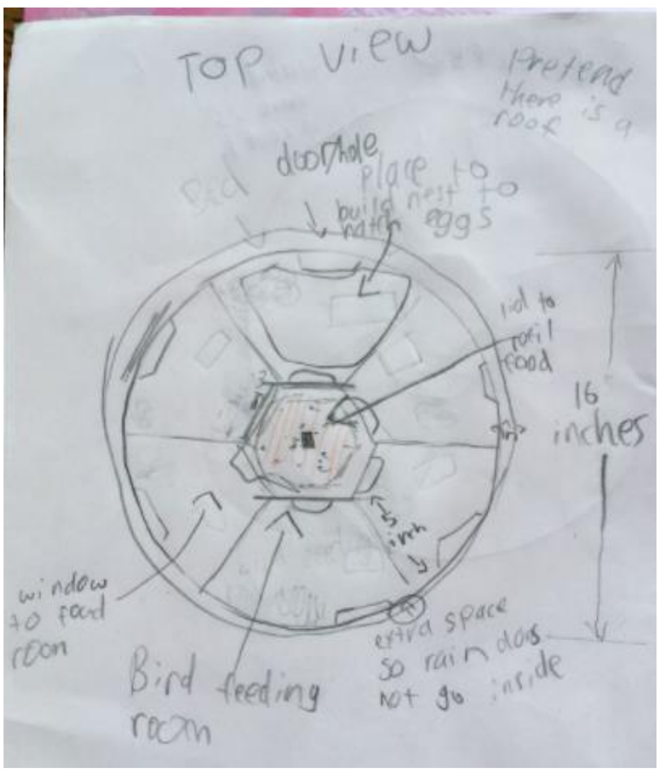


As noted in Figure 5, the Ying family chose to build a stable home for birds, which originally included a range of living quarters such as a mobile home, a mansion, and a hotel. These were alternatives to the primary issues identified around nests (e.g., likely to blow away). The Ying family also discussed possible home features to include such as separate rooms, a shared room for food, and a shower or fountain. For example, as the Ying family agreed on a fountain, Daniel offered his visualization of the fountain.

> But what I was thinking was we have a big bowl of water that has a couple of holes in it. And then the holes are on the top. And it goes down slowly. And there's a giant board so they can just walk in and the water would just drip down on them like from time to time.

In one of the group sessions, they shared that they planned on building a Bird BBnB (Bed, Bath, and Breakfast). As displayed in Figure 6, several of the possible features discussed in the brainstorming process were included in their design sketch such as a "bird feeding room" and separate rooms for each bird "to build their nest to hatch eggs".

Figure 6. Sketch of Bird BBnB



Discussion

The primary objective of this exploratory study was the investigation of heuristic use amongst families participating in an out-of-school engineering program with their elementary aged children. To date, the majority of research on problem exploration heuristics has focused on adult learners [12], [38], and as argued by Watkins et al. [13], simple measures such as frequency of and time spent on heuristics. Through the close examination of various heuristics that the five participating families drew upon when brainstorming and identifying an authentic problem and possible solutions within their home environments, our findings revealed three common heuristic patterns across families, including (a) person-centric, (b) material-based, and (c) place-based. These three heuristics highlight the value of a shared knowledge around people, place, and material in this process, which further supports the argument of acknowledging parents as unique educators as they understand their children, and have knowledge of their lives and experiences, in ways that are unparallel to other adults [22], [39].

Person-centric Heuristics

Several participating families demonstrated a distinct orientation towards individual people or groups in need of assistance. In nearly all cases in this study, the entire project prototype was centered around or inspired by an individual family member and a particular need they had. Employing this *person-centric heuristic*, these families framed their discussion around the individuals for whom a problem was most salient, as well as the affordances provided by various solutions. Using people as the primary guide for identifying problems and brainstorming solution ideas creates a natural boundary or framework within which caregivers and children can think more specifically about a prototype, its use, and functionality.

The Anderson family, for example, employed heuristics framed around specific people in their home (e.g., their mother), whose actions and behaviors would be changed through use of their design. This family also demonstrated people-centric heuristic use in thinking about various solution ideas and working to find one that would "benefit the most people". In their case, it was the applicability and usefulness to others that drove the conversation and the approach was informed by the Anderson's shared experiences with other individuals in their family [32].

Further, with specific individuals in mind, aspects of prototyping and testing are impacted, as measurements, shape, maneuverability, and other features are all dependent upon the size, shape, or strength of the individual one has in mind. Depending upon the nature of the task or problem, visualizing and thinking critically about how a specific person might be impacted by or prefer to handle such a problem dictates further details and components of a prototype. Again in the case of the Anderson family, it was their mother's specific method of watering down low soaps and shampoos that inspired their final prototype design.

Material-based Heuristics

Another heuristic theme that emerged from the data was centered around inanimate objects and appeared to stem from a practical perspective, influenced by accessible materials and tools. Nearly all families gravitated to these *material-based heuristics* at some point in their engineering design project. When they did, they chose to focus not only the practical and accessible materials and elements required for their problem solutions, but also the aesthetic nature of those materials or features and their contextual/environmental aspects. Caregivers often included the use of pragmatic, open-ended questions (e.g., "What are you going to add?" or "So would one of the solutions be to purchase better materials? Because right now, what are we using for this?") to facilitate this discussion [20], [23], [27]. Using materials and tools as the primary framework by which to identify problems or challenges helped provide families with another boundary by which they could explore the various tangible, achievable options that might be available to them.

For example, the Murphy family, employed this heuristic theme, often focusing less on who might benefit but more on the various materials they might use, their respective costs, and how different materials or tools would impact functionality. Similarly, the Ying family centered nearly all of their discussion around the materials needed to ensure a strong Bird BBnB structure and what each of the unique compartments might need that also served various aesthetic functions.

Place-based Heuristics

Nearly all families applied more context specific heuristics to their problem identification and solution ideation processes. In these instances, it was a situation or pertinent location that drove the dialogue and thinking. This *place-based strategy* was observed as families discussed specific contextual or environmental needs and deficits. Looking at their home, yard, and familial spaces, for instance, families discussed what might be achievable within those contexts and framed their exploration of solutions around them, prompting children to take ownership in thinking about their home environments with a new or different lens [31]. In some ways, this heuristic theme informed the use of the former heuristic trends – person-centric and material-centric – and the nature of discussion therein.

In many ways the focus on place began the conversation amongst participating families about the type of problem they could address. This contextual framing allowed for the narrowing of scope of ideas and often led to more nuanced conversation about materials or certain individuals for whom a problem exists. For example, the Hand family first collectively discussed their home environment and various ways they might improve certain spaces. Their ultimate decision to focus on their garden box structure was informed by ways that would improve the functionality of their outdoor space.

As recent research highlights, STEM interactions in out-of-school contexts, particularly the home environment, supports the positive dispositions and identity development of children in a STEM field, as well as encourage the pursuit of a career in one of the disciplines [24], [25]. This study adds to the literature base as parent-child interactions around a self-identified problem and possible solutions provided children an opportunity to engage in problem exploration heuristics more common to developing and practicing engineers than might be expected of novice engineers [6]. This in return may have supported the development of creative activities and processes that are highly regarded in fields such as engineering [3], [40], as well as their identity trajectory as an engineer [41]. While not highlighted in our analysis, the process of problem identification and possible solution ideation was a shared endeavor between child(ren) and caregiver(s). As one example, we observed each member of the Murphey family give each solution a score between 0-5 with the highest score being the solution they designed and created a prototype. As another example, Audrey and Daniel Ying presented their individual problems by posting post-in notes on the wall and each sharing their problem ideas to one another. Caregivers often posed questions to help guide and/or focus their child(ren)'s thinking, seek clarification, or delve deeper into their reasoning.

We acknowledge that this exploratory study is not without limitations. Yet, these limitations highlight possibilities for future research. One limitation is the small number of family participants. We intend to build upon the findings in this study with additional families. Another limitation is that the family households earned more than $75,000 a year. Similarly, the majority of families had at least one caregiver who had a career as an engineer. On one hand, this may indicate a level of engineering literacy, knowledge, and access to an engineering-related culture and resources that the majority of caregivers in the United States would not be able to utilize in a similar program [42], [43]. On the other hand, research has shown how caregivers are able to support their children's development and engagement in STEM activities regardless of their expertise [25], [44]. Future research could replicate this study and/or address a similar research question with a diverse pool of family participants. This may include engaging families in off-line formats. We further advocate for additional research being conducted with families in their home environments. As described by Cian and colleagues [24], the home environment is a site where family values and cultural norms are cultivated to support and validate children's interests, confidence, and aspirations in STEM. Research investigating purposefully positioned programs in family home environments may reveal greater insight into familial or cultural capital-based heuristic use to identify engineering problems and potential solutions.

Implications for Practice

We conclude with a few implications for engaging children and their families in engineering practices and design processes. One, the home environment should be considered a rich site to encourage engineering education between children and their parents, siblings, grandparents, and so forth. Significant research details the benefits children derive from out-of-school STEM learning experiences such as career interests, identity development, and an integrated knowledge base in STEM disciplines [23], [24], [45]. Recent research by Morris and colleagues [46] indicated that families can and often do engage in self-described STEM activities or learning in the home, yet little is known about how such a familiar environment influences engineering learning or use of engineering concepts. Two, engineering problems have historically been characterized as either well-defined problems [47], typical of school and university curricula, and ill-defined problems, those established by a client (e.g., Swenson et al., 2021). In this study, each family was able to engage in a shared and personal problem grounded in family's cultural, familial, and social norms and values (i.e., funds of knowledge). They were also able to use material and resources in and around their home environment, thus exhibiting an ethos of resourcefulness [49]. Therefore, engineering programs for children should integrate parents and caregivers, if not physically, then through other forms of communication or conversations. For example, ask parents to co-construct a few potential problems in the community that their child(ren) can share with their peers. Three, for engineering programs in which engaging and/or communicating with parents and caregivers is not feasible, consider a place-based (e.g., zoo, park, school) or community-based approach to the formulation of an engineering problem, a location in which children in the program have a shared knowledge of the site.

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