Exploring Child Creative Habits of Mind in an Out-of-School Engineering Program

Corresponding Author:
Peter Knox, MPA
College of Community & Public Affairs
Binghamton University – SUNY
P.O. Box 6000
Binghamton, NY 13902-6000
Email: pknox1@binghamto

Sawsan Werfelli
Department of Teaching, Learning, & Educational Leadership
Binghamton University – SUNY
P.O. Box 6000
Binghamton, NY 13902-6000
Email: swerfel1@binghamton.edu

Amber Simpson, Ph.D.
Department of Teaching, Learning, & Educational Leadership
Binghamton University – SUNY
P.O. Box 6000
Binghamton, NY 13902-6000
Email: asimpson@binghamton.edu

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Abstract

Fostering creativity in schools is challenging due to preexisting academic structures, assessment metrics, and curriculum standards. This challenge requires looking beyond schools and traditional curriculum to out-of-school contexts and programs that may encourage what have been identified as 'creative habits of mind'. Within the field of engineering, creativity has been identified as a core component. As such, understanding what creative habits of mind may be fostered through participation in out-of-school engineering experiences is important to garnering engagement and investment in the discipline. This study explored the emergence of children's creative habits of mind through participation in an out-of-school home-based engineering program. Specifically, we sought to answer the research question: *What creative habits of mind emerge through child reflections of their experience in an out-of-school engineering program?* Data was derived from post-program interviews with children from 15 diverse families who participated in the program. Transcripts were analyzed using a priori coding based upon the Centre for Real-World Learning (CRWL) Model of Creative Habits of Mind. The prevalence of various creative habits of mind encouraged through participation were identified. *Imaginative, inquisitive,* and *disciplined* creative habits of mind emerge in the findings as the most prevalent creative thinking processes, with concepts including *playing with possibilities, exploring and investigating,* and *reflecting critically* playing a prominent role in children's perceptions of their experiences. This is significant in that it demonstrates a development in creative, independent thinking in children and a fostering of curiosity, imagination, and problem solving through self-reflection that is inherent and critical to the field of engineering.

Introduction

Calls for enhancing science, technology, engineering, and mathematics (STEM) pathways and experiences have proliferated over the past two decades [1] – [3]. As careers and global job markets continue to evolve and expand, so too does the need for more diverse perspectives and qualified individuals to engage in both new and existing engineering and technological roles [4]. This need has led to an enhanced research effort in STEM engagement during younger years (e.g., elementary and middle school) to better understand how children's early experiences with STEM may influence their interest in various disciplines and educational or career pathways [5]. This effort has been challenging, particularly for the field of engineering, as elementary and middle school teachers often lack confidence or comfort in their experience with or knowledge of engineering concepts [6]. Furthermore, the opportunities and methods for incorporating engineering design principles and experiences in schools tend to look different, dependent on age and grade level. For example, early childhood education might employ broader, open-ended, engineering design work integrated with the arts, while more socially engaged issues and specific community challenges tend to inform middle school engineering learning [7]. These differences in effective instructional method can make provision of teacher training and professional development for STEM and engineering content integration challenging.

Despite this challenge, the benefits from incorporating engineering design principles and instruction into everyday learning are becoming increasingly recognized. English and King [8] found that use of the engineering design cycle provided students with an opportunity to utilize their experience and knowledge of science and technology concepts. Previous research has identified the incorporation of engineering design within K-12 curriculum as a facilitator of student critical thinking, social skills, and learning application [9], [10]. Further, recent research has identified creativity and innovation as particularly important skills within engineering disciplines that can also be supported in children through exposure to novel engineering programs and concepts [11]. Collectively, these skills and competencies have been referred to as 'engineering thinking' and found to be essential within the field of engineering [12]. In his evaluation of the role of engineering in solving new challenges or problems faced by society, Cropley [12] specifically underscored the importance of creativity, positing that engineering and creative thinking are, in essence, one in the same. He noted, "Engineering – as a problem-solving process – connects those new needs and new technologies together. Because creativity is concerned with the generation of effective, novel solutions, creativity and engineering are, in essence, two sides of the same coin," [12, p. 2]. Yet, similar to K-12 engineering content, incorporating creativity and innovation skill development into existing curriculum can be challenging and often looks different across educational settings [13]. This may be for several reasons, including varying teacher perception of what creativity entails, or a mismatch between teacher value of creativity and their use of creative practices and instruction [14].

The connection between engineering and creative thinking [12], combined with difficulty integrating engineering and creativity into existing curriculum within schools, requires looking at alternative settings such as out-of-school contexts. Out-of-school contexts have been identified as beneficial to child identification with STEM concepts and enhancing their positive perspectives on the applicability or relevance of STEM disciplines [15] – [17]. Less is known about how such contexts might support children's creative habits of mind in relation to engineering. Therefore, in this study we explore the emergence of creative habits of mind through participation in an out-of-school home-based engineering program. Specifically, we sought to answer the research question: *What creative habits of mind emerge through child reflections of their experience in an out-of-school engineering program?*

Relevant Literature

The current study is situated within two primary bodies of literature. The first is centered around STEM learning at the elementary levels and how engineering learning, in particular, is (or is not) integrated into typical curriculum. While this body of research is growing, the vast majority is centered around STEM and engineering learning that takes place within schools and classrooms and on student knowledge assessments or conceptualization of the engineering design process [18]. Less is known about how out-of-school contexts might impact engagement and interest in engineering, as well as how noncognitive elements such as creativity and innovation might evolve. The next is centered around creativity development and creative habits of mind. Understanding that engineering and creativity are inextricably linked [19], previous research on creative and engineering habits of mind form a foundation for the current study. This work lends support for further investigation into how creative habits of mind might manifest through participation in an elementary engineering learning program, specifically within an out-of-school environment.

Elementary STEM and Engineering Learning

Scholars have advocated for greater understanding of children's perception of engineering and engineers, particularly as a way to guide reform efforts underway and the development of new STEM curriculum, standards, and practices [20]. As attention on student success in mathematics and science has increased over the past several decades, scholars have posited that the answer to increasing achievement in these key areas can be found within children's experiences during elementary years [21], [22]. Further, Archer and colleagues [23] suggested that children's identities and aspirations towards careers or further learning in STEM disciplines are often formed and solidified before middle and high school. Understanding this, further investigation into the elements that shape student interest and engagement in engineering and other STEM disciplines at younger ages may provide insights for strengthening the STEM discipline pipeline. Several efforts have begun to identify various manifestations of engineering interest during elementary school, but are often focused specifically on students' understanding of particular design processes, tools, or technology [24] – [26]. Dougherty and colleagues [21] also identified elementary years as a critical period in child development in which interest is more flexible and provides greater opportunities for motivating engagement with various STEM and engineering concepts. These results suggest that the experiences that elementary school students have with engineering concepts and tasks, connected to problem-solving and creative agency, can positively influence their perception and interest in STEM [21], [27], [28].

In the development of the Next Generation Science Standards (NGSS), the National Research Council [10] lent support for the integration of engineering learning with other disciplines and content as a way to enhance understanding and interest in the discipline. This time period is also an opportunity to address gaps in understanding that persist amongst elementary aged students about who an engineer is, what they do, and how they might already engage in such practices [20]. Despite growing evidence of the importance of introducing elementary students to engineering concepts and activities, several systemic barriers persist in truly integrating and sustaining these concepts into curriculum and practices in schools. Few students express interest or plans for STEM and engineering careers or experiences, as they're often not exposed to the discipline or its applicability during their K-12 education. This is likely due in large part to the limited or nonexistent training or preparation that K-12 teachers receive in integrating engineering principles into their existing curriculum or content areas [21]. Epstein and Miller [29] corroborated these findings, adding evidence that educators understand the importance of blending engineering concepts with other content but feel apprehensive about their own knowledge and unsupported in their efforts. This, in turn, impacts educators' own perception of engineering, subsequently impacting their approach to teaching engineering and their students' perception of the discipline [30], [31]. Elementary level educators may also feel uncertain in their ability to balance state and school learning expectations and benchmarks with the incorporation of engineering questions and design practices [32]. Persistent barriers as those discussed above require looking to alternative methods and contexts for integrating engineering experiences and content into the lives of elementary aged students and how they might contribute to noncognitive skill and ability development.

Creativity and Creative, Engineering Habits of Mind

Creativity and innovation are complex, multifaceted constructs that manifest in various ways and levels throughout life. Creativity is a skill that can be developed and evolve over time. Treffinger and colleagues [33] discovered an extensive number of definitions in use that could be categorized into broad themes including generating ideas, digging deeper into ideas, openness and courage to explore ideas, and listening to one's "inner voice." These categories were left purposefully broad, with the understanding that creative characteristics and behaviors manifest differently across individuals and disciplines and that various characteristics may emerge or diminish at various times and degrees [33], [34]. Creativity has been identified as an essential skill for several fields and disciplines, including engineering. In identifying the significant connection between engineering and creativity, Cropley [19] noted that creativity is often a staged process that mirrors that of the engineering design cycle. Beginning with Guilford's [35] stages of creativity - problem recognition, idea generation, idea evaluation, and solution validation - Cropley [19] identified the equivalent engineering phases of engineering problem or challenge identification, finding possible solutions, testing and narrowing solution effectiveness, and selection and implementation of the most plausible solution. The development of creativity in engineering does not come without noted challenges. Cropley [19] noted several paradoxes that emerge including the need to, at times, think divergently and convergently about an issue or challenge, as well as the benefit and barrier to creative thinking that can occur through limited structure or oversight.

The complexity of this relationship is in part due to similar challenges in teaching or fostering creativity in formal environments, as well as its assessment. Robinson [36] also identified the duality of creativity development noting control and freedom, conscious and unconscious thought processes, and various methods and mediums all interact and contribute to creativity and learning. These complexities inspired further investigation into how creativity and creative learning is embedded and understood within schools and how it might be evaluated, leading to the development of what the CRWL identified as *creative habits of mind*. Composed of five habits - inquisitive, imaginative, persistent, collaborative, and disciplined - these categories have provided a framework which educators may use to begin to assess and understand influences on student creativity [34]. It was this framework that contributed to the development of specific engineering habits of mind, in an effort to better inform and prepare educators for the incorporation of engineering concepts in classrooms [37]. Akin to creative habits of mind, engineering habits of mind are internalized habits that guide our thoughts and actions [38]. Lucas and Hanson [39] posited that engineering habits of mind (e.g., systems thinking, improving, creative problem solving) can be understood as situated within broader creative and learning habits of mind. The fostering and development of these creative and engineering habits of mind, however, requires awareness of the habit, creating an environment that fosters the habit, teaching or facilitation purposefully supportive of the habit, and fostering learner engagement or commitment to the habit [39]. In other words, creative and engineering habits of mind are both context and individual dependent, necessitating the investigation into various settings and relationships that may facilitate the development of interest, engagement, and creativity within engineering.

Theoretical Grounding

Transformative learning theory has been described as a process of shifting or evolving one's frame of reference [40], [41]. This theory is centered around the idea that as new information is provided and experiences occur, learners' perspectives and thought processes can shift and evolve. Mezirow [41] describes frames of reference as being composed of two primary components - habits of mind and points of view. He goes on to describe habits of mind as "...broad, abstract, orienting, habitual ways of thinking, feeling, and acting influenced by assumptions that constitute a set of codes. These codes may be cultural, social, educational, economic, political, or psychological," [41, pp. 5-6]. In the context of the current study, we focus our attention on creative habits of mind that are illuminated via children's experience within an out-of-school engineering program. In focusing on creative habits of mind, we aim to learn how children's frames of reference and experiences in this type of program may have informed changes in their perspectives and thought processes. In her work at the postsecondary level, Troop [42] examined the relationship between creative activity and transformative learning and posited that transformation was itself a creative process and involved "subjective reframing" or changing of perspectives informed by independent thinking. Our aim is to extend this line of thinking and better understand how creative habits of mind might emerge through elementary aged children's experiences and receipt of new STEM and engineering information. Through children's own reflections and expression of their lived experiences in an out-of-school engineering program, we aim for a deeper understanding of the creative habits of mind that are supported and how that may shift children's frame of reference to engineering.

Methods

This exploratory study aims to investigate the creative habits of mind demonstrated by children who participated in a STEM engineering program in their homes or out-of-school contexts. Using the CRWL model of creative habits of mind [37], an a priori coding structure demonstrating distinct habits of mind was applied to child participant interview data. This coding scheme allowed for the summing and visualization of prominent habits of mind that emerged across all study participants [43]. The inclusion of child participant perspectives from 15 families provides diverse data for the interpretation of narrow units of analysis (i.e., statements, phrases) and aggregation into broader units (i.e., themes, meanings) [44].

Context

This study is part of a larger grant project working in partnership with families and community members to develop, implement, and refine an out-of-school elementary engineering program. The current study explored the perceptions and demonstrated creative habits of mind of children who participated in the out-of-school engineering program during Year 2 and 3 of the larger project. Children's families were recruited for participation through informational fliers, social media posts, and partnerships with local community organizations (e.g., Boys & Girls Clubs, local schools, public libraries). Various program sessions occurred during the Spring and Summer (2020 and 2021).

Over the course of their participation, children and their families engaged in two elements of an at-home engineering program. The first element involved use of take-home engineering challenge kits including facilitation guides, basic materials, and equipment (e.g., popsicle sticks, small motors, hot glue guns, etc.). Kits were designed to introduce children and families to the engineering design cycle, starting with problem identification, to brainstorming/solution ideation, prototyping, testing, redesigning, and communicating results. The second element built off of the design cycle learning from the kits to identify an engineering challenge in their home or community, before designing, prototyping, and testing their proposed solutions.

Participants

Participants in this study were 24 children (16 female) ranging in age from 6 to 12 (grades 1-7) from 15 different families living in a small city in the Northeast US. Participating children and their families were racially and socioeconomically diverse, with caregivers and children self-identifying as Asian (2), Black (3), White (9), and Multi-Racial (1) and with incomes ranging from less than $25,000/year to more than $75,000/year. Five participating caregivers had professional experience with STEM or currently worked within a STEM discipline (e.g., engineering or mathematics PhD; software engineer). The remaining 10 caregivers self-described as having little to no experience with STEM or engineering. Individual pseudonyms have been utilized in the presentation of study results.

Data Source

The data utilized in this study are post-program interviews with the participating children in the program. Interviews were conducted via phone or virtually using Zoom and ranged from 30 to 90 minutes in length. Interviews consisted of open-ended questions and statements posed to children, followed by occasional impromptu probing questions seeking clarification or further detail. Examples of interview questions and statements include '*Describe how you acted like an engineer through the development of your project or in using the kits.', 'What parts of the engineering design process do you still use in your home?', 'Are there other elements/problems you would want to solve or engineer a solution for in that same environment?*', and *'Think about when you started your project - do you feel more/less/the same confidence or comfortable with engineering steps and this type of work?'* All interviews were recorded via phone, voice recorder, or the Zoom recording feature. Interview transcriptions were conducted using available software (e.g., Otter.ai) and paid services (e.g., Scribbie). Transcriptions were reviewed and cleaned by researchers to ensure accuracy and completion.

Analysis

Analysis was conducted beginning with close examination of child participant interviews that were transcribed verbatim. Researchers independently reviewed statements and answers provided by children and identified the most pertinent or closely-related *a priori* code, which were derived from the CRWL model for creative habits of mind. Example codes included *Playing with Possibilities, Exploring and Investigating, Sticking with Difficulty, Cooperating Appropriately*, and *Reflecting Critically*. All a priori codes correspond with distinct creative habits of mind including (a) imaginative, (b) inquisitive, (c) persistent, (d) collaborative, and (e) disciplined. The creative habits of mind and the corresponding codes can be seen in Table 1.

Table 1
Creative habits of mind and corresponding subcategories used for a priori coding.

CRWL Creative Habits of Mind					
Creative Habit of Mind:	**Imaginative**	**Inquisitive**	**Persistent**	**Collaborative**	**Disciplined**
A priori codes:	*Playing with possibilities*	*Wondering and questioning*	*Tolerating uncertainty*	*Cooperating appropriately*	*Reflecting critically*
	Making connections	*Exploring and investigating*	*Sticking with difficulty*	*Giving and receiving feedback*	*Developing techniques*
	Using intuition	*Challenging assumptions*	*Daring to be different*	*Sharing the product*	*Crafting and improving*

Upon completion of coding, the first and second authors met to review the coding process and discuss any discrepancies and arrive at an agreement on the coding schema. Individual codes were then summed for each participating child/family. We then calculated a total count of each code across all participating families to provide a total use score of each code. This process allowed us to identify which of the five creative habits of mind [37] were most prevalent amongst participating children. In this study, we equate emergent creative habits of mind to themes or specific patterns of meaning drawn from directly observable, child perspectives and dialogue [45]. Through examination of prevalent creative habits of mind, we engaged in a synthesized, aggregate discussion about and description of the essence of children's' experiences in order to draw conclusions and generalize across our sample where possible [46].

Results

The current study represents an initial exploration into children's perceptions of their experience participating in an out-of-school engineering program. This exploration of child perceptions provided a foundation from which various creative habits of mind might be identified and begin to answer our guiding research question: *What creative habits of mind emerge through child reflections of their experience in an out-of-school engineering program?* We present the three most prevalent or commonly exhibited creative habits of mind and use examples and interview data to support the use of specific codes and inclusion within each creative habit of mind.

<u>Inquisitiveness</u>
One of the most prevalent creative habits of mind to emerge from the data was 'inquisitiveness'. The CRWL [37] posits that this creative habit of mind is demonstrated through various actions and behaviors, including wondering and questioning, exploring and investigating, and challenging assumptions. Of the 24 child participants in the current study, 20 demonstrated an inquisitive habit of mind through their reflections and statements, and purposeful exploration or investigation of a process, material, or identified issue.

The inquisitive habit of mind was often demonstrated by Beth through reflections on her experience working with engineering kits and on a self-identified project with her father. Beth made frequent statements regarding her exploration of various methods they might use to build their own project, a liquid soap dispenser holder, and her excitement and curiosity about how each step of the process might unfold. When asked about her design process, Beth said:

> *How I like to design is I like to use my... I like to add little details and make it look my way, how I want it to look. I like that you don't just build it, you have to go through step-by-step and a lot of those steps are fun. One of them, designing and it's fun to see what you come up with at the end.*

Upon further questioning about her experience, Beth expressed some shifts in perspective and possibilities for her future in engineering. She stated, "*Well, I really have enjoyed building these last few kits and I just wanna explore more different types of engineering and maybe more of civil."* Through these reflections, we see Beth demonstrate inquisitive behaviors and an aptitude for exploring options and ideas, as well as enjoyment at wondering how her efforts will unfold.

Annie provides another example of wondering about and questioning her environment and working to explore solutions to challenges she observed. While working with both her parents to identify a challenge or issue and begin prototyping, Annie frequently commented on her process and shifts in thinking. For example, when asked her perspective on the usefulness of various materials she used, Annie said, "*Definitely cardboard. I didn't realize how useful it could be for such things, and tape. [laughter] I didn't realize how much you could use tape in just random things that would actually work effectively."* Through further conversation and in response to a statement about her ideation during the design challenges, Annie said:

> *Sometimes it took a little while to come up with a good idea, but after a while, I definitely had a decent idea. The circuit, there was a lot of trial and error with our design, because it took a while for me to figure out what would work best or what would work realistically. So I had a design that I had multiple pieces of cardboard coming out of different places. And then when I really thought about it, it wouldn't really be sturdy and I wasn't sure that the wires would be long enough to fit without actually ripping or anything.*

As implied in this quote, Annie showed a proclivity for exploring options and investigating various methods through trial and error. Through testing of various materials, she demonstrated a process of wondering and questioning, ultimately leading to an idea or prototype she enjoyed.

As a last example, siblings Cassie and Gabe also reflected on their experience with the engineering design cycle. When specifically asked about designing and building, Gabe stated that he loved it, noting the 'figuring out process' or problem solving was enjoyable. He said, "*Because it's fun, like trying to, like making ideas and trying to figure out which one should be, like how to combine that."* When asked about prototyping and her perspective on one of the engineering kit challenges, Cassie reflected on their brainstorming and use of creative ideas, noting:

> *That was one of... I liked that one too, because it was... We turned the toy... We did like, turned a toy into a survival kit, and we each added all of our ideas and we used the*

different like... I also liked the lights and the sounds, and we did a thing where we would pull something and it would make a sound, and that was pretty cool.

Cassie and Gabe's reflections demonstrate enjoyment in the inquiry process and wondering that comes from developing ideas, combining materials, and exploring different approaches to challenges that arose.

Discipline

The next most prevalent creative habit of mind to emerge from the data was 'disciplined'. This creative habit of mind is described by the CRWL as being more non-cognitive in nature and centering around constructs such as crafting and improving, developing techniques, and reflecting critically [37]. In explaining the use of the term "disciplined" as a creative habit, Lucas and colleagues [37] noted that a controlled approach and concerted effort in building, and investment in craft and handiwork, are necessary when working to develop creative things and demonstrate innovation. Of the 24 child participants in the current study, 21 demonstrated a disciplined habit of mind through self-observations of their technique development and assessments of their experience and development in engineering.

In discussing their experience in the program, sisters Eve and Ashley expressed their development and growth in building techniques, their improved use of tools and materials, as well as reflection on their own growth. When discussing their favorite kit project, a "toy hack" that turns an old toy into something new and useful, Eve said:

> *So we took a lot of time with that and we were able to figure out the wiring and the thought process of putting it together… You had to kinda go and tweak it a little bit to keep them working. So I really liked... That was my favorite. We spent a lot of time on that. We spent a lot of time figuring out which light bulb we wanted because they were all different colors. And well, we thought different colors would match different things, and we figured out which one would match a gorilla better, like green, blue and white.*

Eve's reflection demonstrates a tenacity and level of discipline in determining functional circuitry, as well as which light bulb was most appropriate for their design in terms of function and esthetics. Eve and Ashley also demonstrated honest reflection on their experience and provided frank perspectives on how they viewed themselves in the discipline. Ashley said *"It could be like a hobby that you do after work or when you have a free time, like people do painting, they do writing after they do a job, so it's kind of like a hobby,"* which Eve then supported by noting:

> *I can understand why you wouldn't want to do it as your day job, like what you would do for a living, but I could see why you wanna do it for a hobby, because it's just... I feel like you can do whatever you want when you're building so you feel like you have freedom of what you want to do.*

As implied by the quotes above, Eve and Ashley both demonstrate critical reflections and an honest assessment of their experience with the engineering processes. This pragmatism and evaluation of their experience is indicative of a disciplined habit of mind.

Another child participant, Kim, made significant note of her development and evaluated her processes as she went through the engineering kits. In discussing her brainstorming process, Kim said, "*I think because sometimes ideas don't come to my head and then I have to think a lot, and then that takes a lot of time, and then sometimes when ideas don't come to me at all, I have to go outside and then I have to think about the things that will make my life better.*"

This discussion led Kim to reflect on how she incorporates steps of her engineering design process into everyday life, as expressed in the following quote:

> *When I'm doing the kits and in real life, because even in real life, I have to solve things, like problems, and at school, when we're doing obstacle courses, sometimes I get mixed up in the paths and then it's a little hard to follow and then I have to solve for where to go.*

Through these quotes we begin to see Kim's perspective on her experience and her critically reflect on the ways she developed techniques for brainstorming and identifying ways to incorporate elements of the engineering design process into her everyday life.

<u>Imagination</u>

The most prolific creative habit of mind expressed by participating children was 'imagination'. Every participating child (24) demonstrated an imaginative habit of mind as expressed through their creative use of their home contexts, making connections to their lived experiences, and innovative thinking. Often linking imagination closely with creativity and innovation, the CRWL distinguishes this creative habit of mind through the use of intuition, making connections with one's lived experiences or the 'real world', and playing with possibilities [37]. The application of past knowledge or experiences, along with flexible, creative thinking were touched on frequently when participating children reflected on their experiences in the program and their own development and identification with engineering processes and design.

Jerome provided a prime example of this creative habit of mind. In reflecting on his thinking, as well as the environment during the time of his participation, Jerome noted that he had begun to have several engineering solution ideas inspired by his home and community. When asked about what he would engineer a solution for, he responded:

> *Oh, many things. One, one of them is sometimes we need our own space, so that's why I came up with social distancing, which was one of the problems I was doing. And then thought I was like... That's why I came up with the Social Distance Bubble. I'd probably make it out of bendable plastic. You know that kind that they use for pool floaties? Like that. It'd keep its structure by… it's inflatable.*

As demonstrated by this quote, we see Jerome incorporate his current circumstances and lived experience with pandemic-related requirements to make connections to engineering solution. Further, he used his imagination and intuition to play with various possibilities and materials for his design.

Brothers Jake and Sam also demonstrated significant use of imagination and their intuition in working through the design process and program challenges. Jake discussed his frustration at times, but reflected on how he and Sam worked through the process to find a solution. He said:

> *…we had a couple of wires that we had connected to a motor. But yeah, the motor didn't have... Or no, it was the button. Well, uh, the wires were... They weren't really fully stripped. And then I don't think either the motor or the button had wrap around connectors. It was the kind you were meant to solder on. We ended up being able to do it kind of with a glue gun to hold the wires in place. That was one of the ones that we had difficulty with.*

Later in conversation, Sam noted how this process got him to think creatively and play with possibilities regarding other projects or use of other materials from around their home. Sam stated:

> *…it gave us a reason to use different materials we had around like electrical tape and things you could find out in the garage and such, pushed you to look... I don't know if we took a whole bunch of household things, but we definitely took a bunch of stuff from our sort of workshop and part of the house.*

As implied in this quote, Jake and Sam showed use of their intuition and expanded thinking to test various circuitry and electrical possibilities, as well as new materials.

Two sisters who participated in the program - Joy and Helen - also demonstrated great use of imagination and noted their creative thinking around possibilities or ideas to engineer a solution for. Reflecting on her engineering design process, Helen said:

> *'Cause I like the idea of when you... Sometimes, when you just open up a kit, you just have so many different ideas that you can do with the things that come, just... I guess, you think about them and not... Sometimes, it doesn't necessarily have to do with the actual project, but they are still good ideas.*

Joy also reflected on being able to put her creative ideas and intuition into action and thought positively of her ability to immediately apply her thoughts and possibilities. She said, "*Because there's small things that you can put together and you don't have to just think that you can do it. You can actually put it into action and what you think of something and you can see how different things go, and then you can go into it."*

As demonstrated through the child reflections above, immediate applicability of concepts and agency provided through kits and independent projects allowed children to think creatively and use their intuition in solving challenges. Further, the environment in which this program took place, the home, facilitated making connections to their immediate environment and play with various possibilities for solving problems.

Discussion

Utilizing the Centre for Real World Learning model for creative habits of mind [37], we explored the various creative and engineering habits of mind that emerged in 24 children who participated in an out-of-school *engineering* program. Through our research we observed various behaviors and actions across all children, including *Playing with Possibilities, Exploring and Investigating, Sticking with Difficulty, Cooperating Appropriately*, and *Reflecting Critically*. These behaviors and actions corresponded with distinct creative habits of mind, including (a) imaginative, (b) inquisitive, (c) persistent, (d) collaborative, and (e) disciplined. While each broad habit of mind and their subcategories were observed across all participants, in this sample three habits of mind - inquisitiveness, disciplined, and imaginative - emerged as the most prevalent.

The frequency of *inquisitive* habits of mind was understood through participating children's reflections regarding wondering about and questioning various spaces, equipment, and individuals who use them. The vast majority of children indicated frequent use of exploring and investigating, which may be attributable to the structured nature of the program and the purposeful use of the engineering design process. We contend that through use of everyday materials and encouraging children and caregivers to think about their home or community environments in a different way (i.e., through the lens of an engineer), we saw shifts in children's own observations of familiar spaces, their structure, and thinking creatively about how they might change or improve them. Through out-of-school learning opportunities, some of the structural challenges to formal engineering integration into elementary learning might be circumvented [30], [31]. By situating the engineering process in familiar spaces and encouraging free, creative thought, we began to see children think differently about engineering in general (e.g., Beth, Annie) and demonstrate inquisitiveness towards other types of engineering occurring in the local community [7], [28]. While a subcategory of 'challenging assumptions' is also used as a signifier of this habit of mind, we observed much less of this construct amongst participants. This, too, may be a consequence of the structured nature of the program and the instructions or parameters initially provided by the researchers. Future program iterations could consider ways to infuse healthy skepticism and support children's appropriate push-back and critical examination of existing materials, tools, processes, etc.

The next creative habit of mind to frequently emerge was *disciplined*. This habit of mind is observed through children's critical thinking and reflection of their own growth and development, their observations of learning and technique development, as well as the process of crafting and improving through experimentation. Use of discipline as a creative habit of mind has been a source of debate amongst creativity scholars [37]. When viewed in the context of out-of-school engineering and a self-driven learning process, its inclusion viewed through the lens of crafting and improving and technique development becomes clearer. Lucas and Hansen [39] also described distinct learning habits of mind, including resilience and reflection. In our study, we see such learning habits of mind align with creative habits of mind, manifesting through children's reflections on their own understanding of different techniques and methods of testing out various ideas [18]. Eve and Ashley, for example, provided great insight into their own observations of engineering development through testing, thinking critically about what worked for them and what didn't, as well as how they positioned themselves in the discipline. The emergence of *disciplined* as a prevalent theme in our study is indicative of the support for children's creative and innovative thinking in engineering contexts by facilitating engineering craft and technique development [20]. Further, by participating in such a program, children were provided the space to try various ideas, methods, and materials and afforded the time and flexibility to fail, persist, and retest or rebuild based on their learning and critical reflection.

Most prevalent and arguably the most supportive and aligned with creativity and creative habits of mind so essential to engineering was the *imaginative* habit of mind. This habit of mind was identified through children's reflections and observations of independent ideation and playing with all kinds of possibilities in their home environment. Using their intuition about who and what might need 'fixing' or assistance, children made connections to their own lived experiences and those of their families and friends to aid their thinking. Jerome, for example, reflected on his current schooling situation and pandemic-related experiences, which inspired his thinking and imagination around various mechanisms he might build to help others with social distancing. Joy and Helen also noted how the open parameters of the kits allowed them to think freely and imagine various possibilities for approaching the task. We contend that this approach to engineering concepts and design phases facilitated the creative thinking and freedom for children to think outside the box and use their intuition [19]. In this way, the engineering design process is perhaps made more approachable and accessible to younger audiences. When broken down into clear steps, each of which affords the opportunity to think creatively and approach tasks in ways that are unique to the individual, engineering becomes less distant and more applicable and relevant within children's everyday lives [15], [16].

Conclusion and Implications

Fostering creativity in schools may be challenging due to preexisting academic structures, assessment metrics, and curriculum standards (e.g., [13]). This challenge may be addressed by looking beyond schools and traditional curriculum to out-of-school contexts and programs that may encourage what have been identified as 'creative habits of mind'. As such, this study highlighted children's various and multiple creative habits of mind that were fostered and supported through participation in an out-of-school engineering experience alongside family members in their home environments. We contend that the results of this study are indicative of potential affordances that can be provided through an engineering program conducted in an out-of-school context, particularly in a home environment in which barriers such as cost and transportation are diminished [48]. Furthermore, although backgrounded in this study, parent involvement and participation with their children through the home-based engineering program likely contributed to the child participants' creative habits of mind. This highlights the potential role of parents as engineering educators [37]. Therefore, we argue for the collaboration and inclusion of parents within engineering programs and activities, whether in a classroom or school environment or in an out-of-school environment. Lastly, the results from this study may have long-term implications as the call for creative habits of mind have amplified to address the current and evolving economic, social, environmental, and health problems that we face on a global scale [49].

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