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Developing Habits of Mind through Family Engineering at Home

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Developing Habits of Mind through Family Engineering at Home (Fundamental)

Abstract: Engineering in early education provides the foundation for the future of innovation. Reinforcing learning and engineering habits of mind (HoM) at an early age is crucial for expanding students' higher order thinking, potential for lifelong learning, and sense of agency in their learning experiences. HoM is defined as a set of learned or internalized dispositions that inform an individual's behaviors when confronted with challenges. This study addressed two research questions: (1) Which HoM were articulated by children as they reflected upon their participation in a home-based engineering program? (2) What patterns of the children's vocabulary align with the HoM framework? Observational methods were used to examine young children's reflections upon the process of completing low-stakes engineering projects in their home. The participants were 23 children ranging from kindergarten to eighth grade. After they engaged in the ill-structured engineering tasks with family members at home, children joined an online show-and-tell meeting to show their prototype to others while answering various questions about their processes, frustrations, and successes. Findings revealed "Resourcefulness," "Adapting/Improving," and "Systems Thinking" as the most common HoM expressed by children through the show-and-tell meetings. Additional analysis also highlighted how children's articulation of learning and engineering habits of mind were logical (i.e., analytical), confident (i.e., clout), and impersonal. Moreover, children's words were product-oriented, predominantly focusing on the materials and tools utilized to create their prototype. The significance of this study highlights how engaging in hands-on engineering projects in the home has the potential to develop children's dispositions and ways of thinking common to engineers.

Introduction

Habits of mind can be defined as learned or internalized dispositions that inform an individual's actions and behaviors when confronted with challenges and problems [1]-[2]. Habits of mind have been found to support the development of critical thinking and problem-solving skills [3]-[4], which are key skills within the field of engineering, as well as other STEM fields such as mathematics [5]. As described by Alhamlan et al. [3], habits of mind are often discipline-specific. In this paper, we focus on habits of mind within the field of engineering, the values and attitudes engineers often use when making and/or improving things [6]-[7]. In particular, we draw upon Lucas and Hanson's [7] habits of mind framework that identifies and describes six engineering habits of mind and seven learning habits of mind for their potential to inform instructional practices and learning cultures across pre-kindergarten to post-secondary contexts. We used both habits of mind – engineering and learning – for what they both afforded. For example, learning habits of mind include Ethical Consideration, the concern for the impact of engineering on people and the environment, which is not captured by engineering habits of mind but remains a value important to the field of engineering [8-9].

ASEE [10] has described HoM as one component that leads to the development of engineering literate students, and as argued by others [11]-[12], can be seamlessly integrated into the curriculum to support young children's learning development. Additionally, some prior research suggests that practicing and prospective educators may have difficulty planning, designing, and implementing lessons and activities that develop and promote children's HoM as engineers [12]-[13]. This may be due to several reasons such as lack of readiness to teach engineering [14], low engineering self-efficacy and low teacher efficacy related to engineering pedagogical content knowledge [15], lack of engineering pedagogical content knowledge [16], and misconceptions regarding the field of engineering [17].

Out-of-school learning environments may be an alternative setting to develop and promote children's learning and engineering HoM. Multiple studies have indicated that out-of-school learning environments enhance children's development as STEM learners, including their development as engineers [18]-[20]. In this study, we explored the emergence of children's learning and engineering habits of mind through engaging in ill-structured engineering tasks in their home environments. Specifically, we examined the following questions: (1) Which HoMs were articulated by children as they reflected upon their participation in a home-based engineering program? (2) What patterns of the children's vocabulary align with the HoM framework? Through this study, we argue for the inclusion of ill-structured engineering tasks in the home environment as an approach to developing children's dispositions and ways of thinking common to engineers.

To date, the research regarding children's HoM as engineers is often examined within school-based contexts and highlights how the learning environment can support the development of engineering HoM of young children [4], [12], [21]-[24]. For example, Spektor-Levy and Shechter [23] investigated how children's engagement with construction material would impact 4-5-year-old children's engineering HoM. Results demonstrated a significant improvement in children's problem-finding (e.g., check existing solutions) and visualizing (e.g., move from abstract to concrete) habits of mind. In a similar study, Shechter et al. [21] also found positive correlation among four engineering HoMs - systems thinking, problem-finding, creative problem-solving, and visualizing – with the strongest correlation being between problem-finding and visualizing. Lippard et al. [12], too, noted how engineering HoMs were more frequently observed when children engaged with construction materials such as blocks as opposed to art, dramatic play, and sensory materials.

Method

In this study, we employed observational methods [25]-[26] to examine children's reflections upon the process of completing low-stakes engineering projects in their home. Since observational methods do not test for a causal relationship, no control group was formed.

Context

This study took place over the course of two time periods between January 2021 to June 2021 and October 2021 and May 2022. 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. Between January to April 2021 and October 2021 and March 2021, families completed between 4-6 researcher-developed engineering kits in their home environment. Each kit was framed around an ill-defined engineering task as such tasks are more common to "messy" problems inherent in our day-to-day jobs and everyday lives and has been noted as developing learners' engineering habit of mind [3]. As an example of an ill-structure task, the Toy Hack kit tasked families 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.

Figure 1 illustrates two examples of the new toys created from an old toy. The one on the left was transformed from binoculars to a survival kit, and the one on the right was transformed from a stuffed animal into a pencil holder and sharpener. Facilitation guides supported families through an engineering design process – research, plan, create, test, and improve. Additionally, there were prompts throughout the guides to foster reflection and communication. Each kit also included low-cost materials. For example, in the case of the Toy Hack kit, families were provided with materials such as a toy, a screwdriver, a buzzard, Velcro dots, hot glue gun and sticks, and scissors. Families supplemented materials needed for the design of the prototype by using materials from their home environment (e.g., cardboard, food containers). For instance, one family used an X-Acto knife to cut a stuffed animal open. We encourage readers to visit our project website at (blinded) for access to the 12 kits and guides.

Figure 1. *Images of family's new toy*

Between January 2021 to April 2021, the research team delivered two kits to individual family's homes approximately once a month. Between October 2021 to March 2022, schools served as the exchange site for kits. A member of the research team dropped off one kit per month at children's school. The name of their teacher was posted on each kit. Children would also return their prior kit the day before as parents received an email regarding the exchange date. Teachers received an email about the exchange date as well as they would leave and pick up kits from the main office.

Participants

The participants for this study included 16 families from four different school districts located in one county in a state located in the Northeast region of the U.S. Across the 16 families, there were 23 children (12 girls, 11 boys) involved in this study. Though interviewees included both parents and children, only responses from the 23 children were analyzed. At the time of the study, the children were between K-8th grade with the majority spanning grades 3-5. The families self-identified as Asian (4), Biracial (2), and White (10), and reported incomes between $75,000 - $125,000 a year.

Data Source

The data source for this study were virtual show-and-tell meetings that occurred once a month, near the time of the upcoming exchange date. They were offered twice a month – Thursday at 7:00 pm and Saturday at 10:00 am – to provide families with two different options to fit their schedule. These sessions lasted approximately one hour and included two components. One, families shared their decision-making process regarding their identified problem, design sketches and materials, and prototype. Games (e.g., bingo, word associations; see Figure 2) and prompts were developed by the research team to encourage such discussion and for children to present their prototype to others. Prompts include the following (a) What engineer did you feel like with your most recent kit?; (b) What about the prototype made you excited? What about the prototype frustrated you?; and (c) Find something around your house that represents how you felt when working with someone in your family. As noted by Lippard et al. [12], it is important for educators to ask questions to build upon and expand children's use of engineering habits of mind. While the questions posed in this study were not asked within in-the-moment interactions with participants during the completion of the kits, questions were a way for children to reflect upon and articulate how they used engineering habits of mind.

Figure 2. *Interactive games used in show-and-tell meetings.*

EXAMPLE

B	I	N	G
Used something from the recycle bin.	Worked with someone else.	Drew more than 1 design in planning stage.	Experienced and worked through a failure.
Used a long, skinny item.	Used material(s) not in kit.	Used a tool (e.g., scissors, screwdriver, ruler)	Included something that added personality.
Used math in the design and build.	Took something apart.	Had fun with a kit.	Included something with surface area.
Used problem solving skills.	Acted like an engineer.	Put two unique things together.	Learned something new from conducting research.

PLAY ON LETTERS

Find your name on the next few slides.

Add a word or phrase that begins with the letter provided (see letters on the right).

The word or phrase should have some connection to one of your projects.

It is okay if you cannot think of something for every letter.

Be ready to share!!!

- C
- L
- S
- F
- O
- M
- H
- I
- W
- R

Two families engaged in a 10-15 minute design task. As an example, children were engaged in the following design task.

> Using material and tools from around your home, we want you to design a robot version of yourself that represents who you are as an engineer! You can get creative - think about

> what makes the ‘robot you’ unique - can you add designs or patterns or materials that make it seem just like you?

When time ended, children shared their thinking and/or prototype with others.

Data Analysis

After the Zoom recordings of show-and-tell sessions were processed, two researchers independently watched the videos, coded the behaviors using the Habits of Mind framework [7], and discussed the code to reach an agreement. The seven learning habits of mind and five engineering habits of mind are listed and defined in Appendix A. We underlined additions we made to the definitions of the HoMs through the analysis of the data.

For the first research question, coding discrepancies between researchers were resolved with repeated independent coding and subsequent discussions. In one instance, a child described, “We used straws as gutters. And so I have another one [straw] that leads to the ground so when it rains, the water can go down to the cup and the animal can drink water” (3.18.21). Both researchers agreed that this quote demonstrated Resourcefulness and Creative Problem-Solving, but one researcher also coded Ethical Consideration. After presenting evidence that the child exhibited empathy via design thinking, it was collectively decided that the quote should also be included under Ethical Consideration. In addition, two original HoM, Adapting and Improving, were combined into a single code of “Adapting/Improving” due to similar or concurrent manifestations in the children’s speech. For example, one child working on a bot explained, “I tried to stick the battery on the bottom or the top, it just keeps falling, it doesn't move. So the only way it would work was to put it on the side.” The quote reflects a change in both situational mindset and material usage, which is characteristic of Adapting, as well as a continuous effort to make the bot better, which falls under Improving.

To address the second research question, the Linguistic Inquiry and Word Count (LIWC), a text analysis tool, was applied to transcripts of the children’s speech to evaluate vocabulary patterns in each HoM [27]. LIWC was selected because it has been consistently validated as a statistical tool in a variety of research studies and fields [28]-[31]. Four dimensions were selected as primary foci prior to analysis: Analytic, Clout, Cognition, and Tone. Analytic thinking “captures the degree to which people use words that suggest formal, logical, and hierarchical thinking patterns” [32, para. 14]. Cognition, an overarching category for different mental processes, from all-or-nothing language to degree of certainty. Both Analytic and Cognition were selected based on their relationship to the mind. Meanwhile, Clout “refers to the relative social status, confidence, or leadership that people display through their writing or talking,” [32, para. 15] and Tone pertains to the degree of positive or negative emotional associations. Clout and Tone were chosen for the social elements that may shape the development of HoM. Analysis for the four dimensions were processed for every HoM such that the dimensional scores can be compared across HoM. Upon reviewing the results, Analytic and Clout emerged as the two most meaningful dimensions.

Moreover, LIWC has a Word Count (WC) function that orders individual words from highest to lowest total frequency. Since WC incorporated quotes from every show-and-tell meeting, exceeding 200 words, only the top 20 words were selected for further analysis. The 20 words were semantically categorized as product-oriented or process-oriented. Product-oriented words are inherently impersonal, as they refer to physical materials and activities toward the completion of the end product, such as “tape” and “cut.” People-oriented words can be either interpersonal or intrapersonal, such as “felt” or “decided.” Such words reflect the speaker’s internal state or describe the speaker’s interactions with other participants. These two categories emerged from the researchers’ individual analysis of the words.

Results

Research Question 1

The most commonly articulated HoMs were two engineering HoMs, Adapting/Improving and Systems Thinking, followed by two learning HoMs, Reflection and Resourcefulness. These top four HoMs had respective total counts of 48, 42, 39, and 34 (see Table 1). This means that the engineering tasks required them to adjust their behavior to new challenges (i.e., Adapting/Improving), examine how parts interact with the whole (i.e., Systems Thinking), consider their own role in the project (i.e., Reflection), and leverage available materials to their advantage (i.e., Resourcefulness). It is possible that Adapting/Improving had the highest total count because it combined two original HoMs, though it was not considerably greater than Systems Thinking, the next highest count. Systems Thinking was identified in quotes that highlighted the inner workings of a machine. One child explained, “We used it [glue gun] for the rain gauge. We used it to glue on the paper clip so it was in the cup. ... It [paper clip] connected to the battery so it would light up” (1.6.22).

Table 1. *Frequency counts for Learning Habits of Mind and Engineering Habits of Mind.*

Learning Habits of Mind		**Engineering Habits of Mind**	
Name	**Total Counts**	**Name**	**Total Counts**
Reflection	39	Adapting/Improving	48
Resourcefulness	34	Systems Thinking	42
Resilience	24	Visualizing	21
Collaboration	14	Creative Problem-Solving	14
Ethical Consideration	14	Problem-Finding	5
Curiosity	9		
Open-Mindedness	7		

It was evident that many of the kits involved children working with their siblings or parents, as they would rotate explaining their shared creative process during the show-and-tell sessions. However, the children only moderately acknowledged Collaboration at 14 counts.

The three HoMs with the lowest total counts are Problem-Finding, Open-Mindedness, and Curiosity, at 5, 7, and 9 counts respectively (see Table 1). This indicates that the children were less likely to acknowledge behaviors related to research, inquisitiveness, and receptivity to feedback in their engineering process. An example of Problem-Finding is when two children decorated a shoe prototype for Serena Williams because they proactively "did research and found those were her favorite foods." Additionally, questions posed by children such as "What sort of engineering is involved with designing mechanics of engines or robotics?" are characteristic of Curiosity.

Research Question 2

The LIWC analysis revealed that certain HoMs are more related to the demonstration of leadership skills or logical thinking (i.e., Clout). The Open-Mindedness HoM had the highest score in the Clout dimension at 71.68, whereas the Visualizing HoM scored the lowest at 26.21. This suggests that vocabulary patterns coded under Open-Mindedness display relatively higher social status, confidence, or leadership [25], [30]. By extension, cultivating openness to different ideas, feedback, and change may be conducive to fostering social mobility in young students. Visualizing, which entails planning or imagining the end product (see Appendix A), most likely has a low Clout score because it lacks the social element of confidence or leadership.

Resourcefulness had the highest Analytic score of all the HoMs at 53.53, while Reflection had the lowest at 21.78. High scores of Analytic thinking are more rewarded in academic settings, as they are correlated with grades and reasoning skills. Instances of low Analytic thinking correlate with a tendency to use language that is more intuitive and personal [27], [32]. In other words, cultivating Resourcefulness may boost academic performance. On the other hand, language under the Reflection HoM "tends to be viewed as less cold and rigid, and more friendly and personable" [32].

Besides the Clout and Analytic dimensions, total frequencies for individual words revealed notable vocabulary patterns (see Table 2). The 20 most commonly articulated words were predominantly product-oriented, as opposed people-oriented. Seventeen out of the 20 words are product-oriented (e.g., "light," "stuff," "pull," and "cut"), which comprise both nouns and verbs related to the impersonal usage of materials in the projects. "Felt" was the only word that was people-oriented, referring to intrapersonal or interpersonal interactions. Though Reflecting was among the four most frequently exhibited HoMs, the children rarely displayed personal and emotionally charged vocabulary. Besides "felt," emotion words such as "frustrated" and "mad" were only articulated six and five times, respectively.

Some words take on substantially different meanings in different contexts. Sentiments of frustration or relief are often associated with the usage of "work," as the word is almost exclusively applied in the context of a prototype working or not, as opposed to people working. This further illustrates the children's focus on the end result over the process of engaging in the projects. Similarly, “time” was overwhelmingly referred to the many innovative iterations. The children’s frequent usage of both words highlights a pattern in the engineering process: frustration from many failed attempts and relief when it finally works. In contrast, “right” does not have a stable pattern of usage, ranging from “right size” to “right now.” Additionally, usage of “together” predominantly involved products, as opposed to people. As one child exclaimed, “The soccer bot had to put together the battery, the motor, and the switch” (3.18.21). Interestingly, “together” was not used to mean working collaboratively.

Table 2. *Frequency counts by word, rows with the word, and percentage of rows with the word.*

	Word	Frequency	Example
1	light(s)	48	“I would use a parallel circuit because if one **light** goes off, the other will continue working.”
2	tape	39	“Maybe we could take this, **tape** it or drill it on a tree or something.”
3	work	36	“It didn't **work** the first time, so we tried a second time and it didn't really **work**. It just didn't move.”
4	water	29	“So we were reading in the kit that the purified **water** did not have the same ions as tap **water** so it wouldn't conduct electricity as well.”
5	time	25	“We researched it online and took quite a bit of **time** online, and realized to make it that it was more complex than we realized.”
6	paper	25	“I made these long **paper** poles to hold up my rollercoaster.”
7	box	24	“So we decided to take a **box** and cut the head and the arms.”
8	felt	23	“I felt mad because I kind of wanted to do it on the first try.”
9	stuff	21	“Because I'm holding **stuff** because I'm looking at **stuff** and I'm experimenting with **stuff**.”
10	things	20	“I kind of don't like those kinds of **things** because I actually like instructions that I can understand.”
11	right	18	“Like measure if it was drooping all the way down or wasn't the **right** size.”

12	wires	18	“Well we put the two red **wires** together, it made a big sound like an electrical sound.”
13	battery	17	“And then we put the **battery** on one of the tape and we put the tape on top so when you closed it, it would complete the circuit.”
14	cardboard	17	“Because dog houses are usually made out of real wood, but we used **cardboard** so I thought that was a little creative.”
15	marble	17	“And we made the **marble** roll down the roller coaster.”
16	pull	17	“So I kind of just **pull** this string and I bring this thing up. And then I kind of let go of it… like all the way.”
17	cut	17	“I **cut** the ends and retaped them back on.”
18	together	17	“Then I put the two bottom ends **together** right here.”
19	shoe	17	“They decided to make a **shoe** for Serena Williams. Which has pizza, ice cream, and tacos because we did research.”
20	house	16	“I messed up for the animal **house**, couldn't figure out how to get door to move.”

Discussion

The objective of this study was to investigate how learning habits of mind and engineering habits of mind are manifested in young children as they complete engineering projects in their home environments. More specifically, children’s articulation of their projects was examined for most frequently displayed HoM and vocabulary patterns that reflect HoM development. Recent research has emphasized the importance of cultivating discipline-specific habits of mind, particularly engineering HoM for furthering STEM learning [10]. Moreover, out-of-school learning environments emerged as a viable area to sharpen children’s HoM as engineers, especially in light of challenges for educators to incorporate engineering HoM into the curriculum such as low engineering self-efficacy and low teacher efficacy related to engineering pedagogical content knowledge [15].

Our findings revealed that Adapting/Improving, Systems Thinking, Reflection, and Resourcefulness were the four most common HoMs. This aligns with prior research on how informal, low-stakes learning environments can foster key dispositions and cognitions that are characteristic of engineers [19]-[20]. Unlike Spektor-Levy and Shechter's [23] study, Problem-Finding was the least demonstrated HoM and Visualizing had moderate counts, only slightly above the median of 17.5. Though it was clear that the children engaged in Problem-Finding, they did not discuss it at length during the show-and-tell sessions. They could have described Problem-Finding in response to prompts about overcoming a challenge, but they instead emphasized their emotional reaction or most recent solution.

Based on dimensional results from LIWC, Open-Mindedness scored highest in Clout and Visualizing scored lowest, whereas Resourcefulness scored highest in Analytic and Reflection scored lowest. Since Open-Mindedness refers to receptivity to new ideas and different possibilities, it makes sense that it correlates with Clout as it pertains to social status, confidence, and leadership. Open-Mindedness is vital to engineering because it signifies the drive to transcend one's own assumptions, challenge the status quo with scientific inquiry, and generate innovations that will expand disciplinary boundaries. Furthermore, Open-Mindedness is increasingly important for a globalized world that relies on information technology and co-creation on various STEM initiatives [32]. Both Open-Mindedness and Clout require an ability to manage diverse interests in a social setting. Visualizing might have scored lowest in Clout because the children experienced the most conflict during the planning phase of their projects and tended to staunchly defend their own ideas. It is also expected that there would be a relationship between the Analytic LIWC dimension and the Resourcefulness HoM. Resourcefulness necessitates prioritization and manipulation of different resources based on their properties and thus entails the formal, logical, and hierarchical thinking that defines the Analytic LIWC dimension.

Additional analysis using the LIWC Word Count function demonstrated that children gravitated toward product-oriented, impersonal language over process-oriented, sentimental language. This may be explained by the design of the engineering tasks. Though they were ill-structured, there was a large emphasis on the novelty of materials and end products. Engineering may be inherently results-driven, as well. Whether or not the product "works" determines feelings of success and sustained interaction with the kit. When the roller coaster is not functional, then the children would describe their repeated attempts to address the problem. When the code for the bot was functional, then the children would stop interacting with the kit.

Primary limitations include sampling method, prompt delivery, and text analysis. Since the study occurred during the COVID-19 pandemic, obtaining a representative sample of the population (e.g., socio-economic diversity) was difficult. Another considerable factor was how some of the show-and-tell prompts may have shaped the children's articulation. If the prompt incorporated the types of materials used, the children would be more inclined to display signs of Resourcefulness. If the prompt focused on the experience of overcoming an engineering challenge, the children would most likely reveal Resilience or Adapting/Improving. Furthermore, some children are more expressive than others in social and virtual settings. They may offer varied descriptions for their process or product depending on the audience and what is at stake. For instance, a casual conversation with their parents, an online interview with a stranger in formal attire, and a graded presentation to an art teacher would likely collect different results. It is difficult to attribute the results to the children's experience, the design of the kit, or the context of show-and-tell sessions. Lastly, LIWC does not capture the context of each word in its Word Count function. A word can be used many times, but the frequency is not as significant if it is used for different meanings most of the time. LIWC also differentiates between different forms of a word, such as "light" and "lights." We contend that additional research on learning and engineering habits of mind are warranted, particularly within different learning environments and through use of different materials as alluded to by Spektor-Levy and Shechter [23] and Lippard et al. [12]. As such, we plan to examine young children's habits of mind as exhibited in their engagement with the various kits with their family members in their home environment.

Implications for Practice

We conclude with implications for expanding the application of HoM in programming with young children and their families. Combining engineering activities with show-and-tell exercises encouraged students to reflect upon their experiences as engineers, particularly the attitudes and emotions they exhibited as engineers when making and/or improving things [7]. The significance of this study highlights how engaging in hands-on engineering projects in the home has the potential to develop children's dispositions and ways of thinking common to engineers. Educators across the STEM learning ecosystem may consider supplying out-of-school engineering exercises to develop children's habits of mind as engineers. For example, a kit can be distributed once per month with a show-and-tell session at the end of the month. To address limitations in this study, educators may provide a more consistent set of prompts that targets each HoM of interest equally. Parents may be advised to more explicitly encourage team formation within the home to foster Collaboration and incorporation of outside resources to cultivate Resourcefulness. Given the importance of Open-Mindedness in STEM and leadership skills [34], parents can be encouraged to include divergent thinking prompts to facilitate children's ability to consider outside perspectives in conjunction with their own. This would address the low frequency count of Open-Mindedness.

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Appendix A

Learning Habits of Mind		
Name	**Definition**	**Example**
Curiosity	Demonstrating inquisitiveness, a desire to learn or experiment, and a passion for discovery.	"It has opened up an opportunity to see how circuits work like we have never tried anything like that before. So it opened up an opportunity." (3.18.21)
Open-Mindedness	Embracing new ideas or scrutiny from others, considering the different possibilities, and displaying willingness to change in the light of evidence.	"I wanted to do one thing and she wanted to do another. And then we got into a big fight about who's idea was better. She let me put a bird bath in the birdhouse and a landing cushion." (2.24.22)
Resilience	Persevering in the face of difficulty, especially when their own failure has occurred, and tolerating the process of learning.	"It didn't work at first when I didn't know how to get on site or how to code it and connect it to the computer. We tried again and went on the site and read the instructions and it worked." (1.29.22)
Resourcefulness	Seeking coherence, relevance, and meaning in different resources. Thinking rigorously and methodically. Making good use of resources.	"I used a box from recycle and I used toothpicks to hold pieces of cardboard, so wouldn't slide when you put the cardboard down." (2.18.21)
Collaboration	Leveraging the perspectives, knowledge, and capabilities of team members to address design challenges.	"I helped him [dad] put the tape down [pointed to conductive tape]. He helped me putting this extra layer of tape down so we could push it down easier so it would work." (2.26.22)
Reflection	Understanding yourself as a learner, exhibiting a healthy skepticism, and monitoring the self along the way.	"This kind of represents us because we like the fidget toys that came out this year and we're funny and we're artistic. So we used this stuff because we didn't want to go outside and grab recyclables in the cold and dark night." (4.22.21)
Ethical Consideration	Attending to the impacts of engineering on people and the environment, including unseen	"We also added stop signs and we made a parking lot. And it has pay for parking. And we also have a bench. A

	consequences for certain groups or individuals. Demonstrating empathy through design.	jumping pad that kind of works. It's made out of pillow fuzz." (4.22.21)

Engineering Habits of Mind

Name	Definition	Example
Creative Problem-Solving	Applying techniques from different traditions and generating novel and useful solutions to an identified problem.	"Cozy gorilla. Because our gorilla was in the toy hack and it was fuzzy. We had to chop it up. We felt bad chopping it up, (inaudible) We made it into a jewelry hanger. We cut the gorilla's head and arms off." (3.18.21)
Problem-Finding	Clarifying needs, checking existing solutions, investigating contexts, verifying. Gathering evidence, potentially through research.	"We researched what makes a good shoe and want it to be between 6 and 12 mm for the sole. So we figured out that we had enough foam to make 6 mm and we figured he wanted it to be flexible, but supportive. So we thought it would work for that purpose." (1.29.22)
Adapting/ Improving	Changing both mentally and physically. Reframing, reviewing, and responding, but also reworking materials to achieve desired products. Relentlessly trying to make things better by experimenting and prototyping.	"Mine when I tried it and I tried to stick the battery on the bottom or the top, it just keeps falling, it doesn't move. So the only way it would work was to put it on the side." (2.18.21)
Systems Thinking	Understanding part-whole relationships, recognizing patterns and interdependencies (Kelley & Cunningham). Considering how the parts, such as materials or concepts, interact to form a whole or end product.	"This was our rollercoaster. This was the shoot that it went down and as it hit the bottom they had to make it build up enough momentum and then the marble went back up. And this was covered, this last end part was covered so that it could slide down." (4.22.21)
Visualizing	Moving from abstract to concrete, mental rehearsal of physical space and of practical design solutions. Engaging in forward thinking; planning or picturing the end project.	"I've got an idea for this. I could cover it in peanut butter and put bird seed on it. Drill a hole here and hang like a really strong rope on it." (3.18.21)