

## **Investigating Children with Autism’s Engagement in Engineering Practices: Problem Scoping (Fundamental)**

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## **TITLE: Investigating Children with High Functioning Autism's Engagement in Engineering Practices: Problem Scoping (Fundamental)**

### **Abstract**

In the last two decades, pre-college engineering education has been on a sharp rise. However, limited research, if at all, considered aspects of engineering thinking of children with disabilities. Therefore, in line with the call for diversifying engineering education, considering inclusion of children with disabilities is necessary.

Among different disabilities, the number of children with autism is rapidly growing. In addition, studies have shown that individuals with autism have the potential to perform well in activities that require systematizing abilities like engineering. Given the importance of participating in engineering learning opportunities from childhood and its impact on future engineering performance, engaging children with autism in appropriate engineering experiences is necessary. Therefore, we need to gain a deep understanding of how they engage in engineering learning activities.

This study is a part of a bigger project in which we aim to characterize engineering thinking of children with autism. In this study, we are closely looking at the first and very important engineering practices; problem scoping. The main purpose of this study is to investigate how 8-10 years old children with autism engage in problem scoping. We focused on three main components of problem scoping in engineering design (1) Problem Framing, (2) Information Gathering, and (3) Reflection.

For this study, we have conducted a qualitative single case study analysis. We carefully chosen one case of child with autism. The child is male and 9 years old and participated in this study with his parent. They were asked to solve an engineering problem of building a roller coaster for a local amusement park in 60 minutes. Their interaction was videotaped and pictures of their designs were captured. We have analyzed the video data using a video analysis approach based on the codebook we developed by reviewing literature on problem scoping. The instances that we have seen in mom-child interactions and conversation provided evidence that the child with autism was capable of engaging in all three actions of problem scoping. The behaviors we have observed were mostly associated to Problem Framing and Information Gathering. However, we have seen some evidence of Reflection. We believe, that the findings of this study lays foundation for future studies on children with autism and engineering design, and how to effectively engage in them in these activities.

# **TITLE: Investigating Children with High Functioning Autism's Engagement in Engineering Practices: Problem Scoping (Fundamental)**

## **Introduction**

Along with minorities and women, people with disabilities are also underrepresented in engineering education and the world of practice [1]. Among different disabilities, autism is the fastest growing population. In the next decade, over half a million children with autism will enter adulthood [2]. Autism is a neurodevelopmental disorder that is associated with certain characteristics that can be categorized as systemizing and empathizing abilities. According to systemizing and empathizing theory [3], individuals with autism usually have superior systemizing abilities, but impaired empathizing abilities. Empathizing includes attributes to understand others' emotions and thoughts. Having impaired empathizing abilities generally will result in difficulties in social skills. On the other hand, systemizing refers to the abilities to predict and control the behavior of systems and to analyze and/or build any kind of rule-based systems by identifying the input-function-output rules [4].

## **Literature Review**

### **Engineering for children**

Having technology and engineering skills and knowledge has become important now more than any time before. Historically, being technology and engineering literate was necessary for some specific vocations. However, we are now witnessing a shift to fluency-based approach to digital literacy [6]. These skills are necessary to live in 21<sup>st</sup> century which heavily relies on technology. Thus, children are required to be both technology and engineering literate as they step in adulthood. Pre-college engineering education can play an important role to equip children with these competencies and skills by providing them appropriate engineering experiences.

Children as young as preschool age can engage in engineering activities and are able to solve engineering problems. Children can engage in competencies that are comparable to experienced engineers. These competencies include asking questions, cause-effect explanation, iterative problem solving, identifying the problem, generating ideas and modeling their solutions [7][8]. However, studies show that these competencies are not exhibited in undergraduate students [9]. Thus, we can argue that pre-college engineering exposure should help children promote these competencies by engaging children in age and developmental-appropriate activities in-school and out-of-school.

Engineering design plays a crucial and important role to have an effective K-12 engineering education [10][11]. However, to have an effective engineering design integration, we need to know how to successfully implement appropriate engineering design activities for variety of learners. The NRC report [11] makes recommendations for conducting research to determine what works for diverse learners and why. They suggest that before creating any engineering learning opportunities, we should explore how different children develop design ideas and competencies and how educators and researchers can support them. Since the number of children diagnosed with autism is growing [2] and they are attending inclusive classrooms more than any time before, the need for investigating ways they engage in engineering design is necessary. Previous engineering education researchers have also called for more investigations on autism and engineering [12]. However, researchers mostly focused on using engineering-related

activities (i.e. using LEGO bricks, robots or makerspaces) to improve children with autism's social interactions [e.g. 13, 14]. Research has yet to explore engineering thinking of children with autism and to identify their strengths and weaknesses in relation to solving engineering problems. Therefore, the focus of this research project is to explore engineering thinking amongst children with autism. As a first step, in this study, we investigate the engagement of children with autism in the engineering design practice of Problem Scoping.

## **Problem Scoping**

Engineering design problems are usually complicated and unpredictable [15]. According to Jonassen, Strobel and Lee [16], to solve these problems engineers (both novice and experienced) may need to consider sub-problems and rules that can conflict each other and sometimes unstated and unidentified. These sub-problems can include, but are not limited to, criteria and constraints of the problem. In addition, the nature and level of "structuredness" adds to complexity of a problem [17]. Structuredness of a problem is the most descriptive dimension of problem solving as problems vary from well-structured to ill-structured. Engineering design problems often have features and sub-problems that fall towards the end of the continuum of structuredness and are called ill-structured. However, depending on how designers interpret and interact with a design problem, even those design problems that are seemingly straightforward and well-structured can be treated as ill-defined with underspecified rules [18]. Therefore, many researchers argue that the ill-defined nature of design problems can be attributed to the features given to a task as well as the way the task is interpreted and scoped [19].

Problem scoping is the first aspect of engineering design mentioned in a comprehensive matrix that Crismond and Adams [20] developed by synthesizing research literature on design. Studies on undergraduate students and professional designers have found correlations between problem scoping and the quality of the final solution for designers of different ages [e.g. 9, 21]. These studies highlighted significant differences between novices and expert designers. In addition, Crismond and Adams [20] claim that beginning designers treat a design problem as well-structured and straightforward. They posit that beginning designers believe that there is one single correct answer and they can immediately attempt to solve the problem which is a threat to the quality of their solution. Crismond and Adams [20] emphasize the importance of training students to engage in problem scoping and provide strategies for teachers to help students practice problem scoping.

Problem scoping is an important phase of addressing engineering design problems; however, it is understudied for young children [23][7]. The limited number of researchers who have investigated children's engagement in problem scoping provided evidence of children engaging in different behaviors associated with problem scoping during their design activities. In one study, Dorie and colleagues [7] investigated design behavior of 4-11 year-old children. They observed children engaging in problem scoping behaviors such as identifying the problem and understanding the goals, identifying constraints, and familiarizing themselves with available material. In addition, Watkins and her colleagues [19] provided evidence of fourth graders engaging in three phases of problem scoping as naming, setting the context and reflecting. Finally, Haluschak and her colleagues [22] investigated problem scoping in young children (K-2 grade) during an implementation of a STEM+C+Literacy curriculum. They found that children

can participate in meaningful problem scoping in all three phases mentioned by Watkins and her colleagues [19, 22].

While these previous studies provided evidence that children in different elementary grade levels are capable of engaging in problem scoping, children with diverse abilities (e.g. those on autism spectrum) have not been a point of conversation. Through this study, we are taking an important first step to explore engineering design thinking of children with autism whose abilities may be different than the majority of the population.

### **Purpose of the Study**

This paper is a part of a bigger research project that aims to characterize engineering design thinking of 8-10-year-old children with autism. In this study, we focus on problem scoping behaviors of children with autism. The question that we seek to answer is,

*“What does problem scoping look like when enacted by a 9-year-old child with mild autism as he engages in design tasks with different structures?”*

### **Theoretical Framework**

Building on previous studies, we believe problem scoping includes two actions that Crismond and Adams [20] describe as, “understanding the challenges” and “building knowledge.” Consistent with previous empirical studies, in this study, we call these actions problem framing and gathering information respectively. Additionally, we consider the importance of reflection in problem scoping as stated by Schon [25]. All three of these actions of problem scoping are also embedded in the model provided in the study by Watkins et al which studies the same age participants as this study. Therefore, the Problem Scoping Framework of this study includes all three actions. We have then added behaviors that can be associated to problem scoping actions by reviewing findings of empirical studies that investigated design in children and adults [23][7][25] [9], and characteristics included in Crismond and Adams’ matrix and Next Generation Science Standards [26]. Table 1 illustrates this framework.

While we acknowledge that drawing a boundary between each of these actions is not always easy, cognitively, children engage in different behaviors and tasks when engaging in these actions. For example, exploring material may seem similar to evaluating the properties. However, exploring material is when children gather information about the material they have access to, but evaluation of the properties of material is when they decide whether or not they can use these materials to solve the problem.

**Table 1.** Problem Scoping Framework

Understanding the boundaries of the problem	Problem Scoping Actions	Behaviors
	Problem Framing	<ul style="list-style-type: none"> <li>a) Reading, rereading, rehashing or reframing understanding of the problem statement and/or the goal</li> <li>b) Identify and restate limitation of materials, space and resources (constraints)</li> <li>c) Identify and restate desired features of a solution (criteria)</li> <li>d) Add/consider meaningful context</li> </ul>
	Information Gathering	<ul style="list-style-type: none"> <li>a) Exploring material</li> <li>b) Gathering information/building understanding of how a system/mechanism works and users</li> <li>c) Gain domain-specific knowledge through group collaboration</li> <li>d) Identifying pieces of information in a problem that span across different categories</li> <li>e) Considering interactions among problem requirements</li> <li>f) Balancing and prioritizing the different components and interactions in a problem</li> </ul>
	Reflection	<ul style="list-style-type: none"> <li>a) Evaluation of the properties and behaviors of supplied material</li> <li>b) Explicitly acknowledging and evaluating the problem space and the decisions made about what to consider and prioritize</li> </ul>

## Methods

### Research Design

Case and Light [27] called for the need to consider more diverse methodologies to conduct research in engineering education. Adding to that call, Watkins and her colleague [17] showed how narrowing the focus of research to a very small group of participants can uncover what participants are able to do. Therefore, in this study, we have conducted a qualitative single case study across multiple challenges to investigate a child with autism’s engagement in problem scoping. Previously, many studies have utilized single case studies in STEM education research, and particularly engineering education. For example, Stewart and Jordan [32] explored the experience of one girl during a robotic after school program and provided insights on the girl’s learning and the barriers to her learning. In addition, Scolnic, Spencer and Portsmore examined engineering learning moments of children with disabilities [33].

Case study is an empirical inquiry which can provide an in-depth exploration of a phenomenon within a “bounded system” that is called a “case”[28]. Case study analysis can be conducted

employing one individual case when in-depth and descriptive evidence is provided to interpret critical events [29]. In addition, in case study, the investigation should be conducted in a specific context [30].

In this study, the phenomenon under exploration is problem scoping within the bounded system (case) of a dyad of parent-child with autism. While the focus of the study is the child's engagement in problem scoping, we also look at the parent's interactions and conversation that help the child engage in problem scoping. The context of the study is an engineering design activity which consists of four different challenges that have the same theme, but are different in nature and structure. We investigate the child's engagement in problem scoping across all four challenges which provides a rich description of how the child engages in problem scoping.

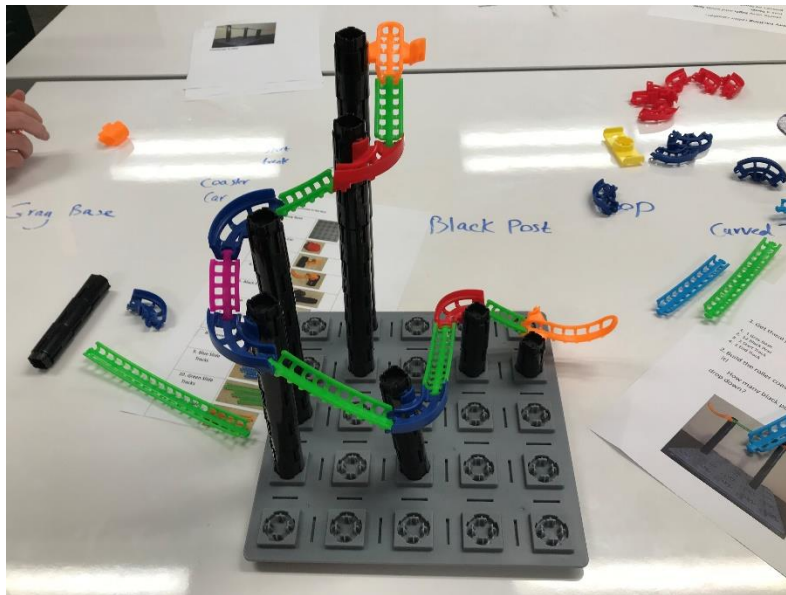
### **Participants**

A family of a mother and a male child with autism participated in this study. The child is 9 years old and attends 4<sup>th</sup> grade in a public school but receives some individualized educational programs (IEPs) at school. The child is diagnosed with mild autism which is historically called high functioning autism. Based on the information we receive from the mother's and child's interview and survey, the mother indicated that she is very involved with this child's education and thinks she knows how to help her child with designing, creating and building ideas and skills. The child's favorite game is a computing game called Minecraft. He has previous experience of playing and building things with LEGO blocks and daily plays with toys that allows him to "design, create, or build". The child has an older sister who is in 8<sup>th</sup> grade who came to the study site but decided not to participate in the study. They have identified their race as "White". In this paper, we refer to the mother as Mom and have given the pseudonym John to the child.

### **Design Activity: Design a Rollercoaster**

The family was asked to try out an engineering design activity in which they had to design and build a rollercoaster for an amusement park. The activity was done in an out-of-school setting in a laboratory of a research institution. In this activity, the family received two letters from the director of a hypothetical amusement park. The first letter stated the problem of a need to have a roller-coaster in the park. It introduced the context of the problem and provided instructions about the next steps. The second letter specified criteria and constraints of the problem. The family had to use a construction kit (Figure 1) to build their solution, but markers were also provided to sketch their ideas if necessary. The activity was organized into four challenges that ranged from well-structured to ill-structured.

Figure 1. Rollercoaster built by the child



### Data Collection and Analysis

The data source that we used for this study was video recordings of the family while interacting with the activity. We stationed two video cameras across the room in which the study was conducted. One researcher who was collecting data also took fieldnotes about what she observed. The video data was 50 minutes long in which both child and mother were deeply engaged in solving the problem and designing the rollercoaster. To do video analysis, we utilized a video analysis process suggested by Powell, Francisco, and Maher [32]. Following this process, we engaged in (1) viewing attentively the video data, (2) describing the video data, (3) identifying critical events, (4) transcribing, (5) coding, (6) constructing a storyline and (7) composing a narrative. One of the researchers was mainly involved in analyzing the videos, however, the second researcher was involved in the process of inter-coding agreement, constructing a storyline and composing the narrative. Step 6 was when we coded the narrative while watching the video if needed. We coded the video against different behaviors mentioned in the framework by focusing on what the child does (interactions with the kit) and what he said (dialogue with his mom and talk aloud). The codes (i.e. behaviors) were then classified into the main three actions of problem scoping. The last two steps happened as we were making sense of the findings and writing the paper.

### Findings

In this study, we aimed to explore how a child with autism engaged in problem scoping behaviors across different design challenges. The structure of the challenges varied between well-structured to ill-structured. The activity started by the first letter from the director of an amusement park, and continued by four challenges. The first challenge asked the child to build the same rollercoaster model provided in the problem. The second challenge built off of the first challenge and asked the child to build a rollercoaster that was steeper than the first one. The third challenge was to build a rollercoaster with a turn of the car before it stopped. Finally, the last challenge was when child received the second letter with three criteria and two constraints.



Below, in a narrative way, we describe events that the child engages in problem scoping behaviors. Within each narrative we have included the codes in parenthesis which refer to the action and the certain behavior. In addition, the narratives include descriptions of what was happening and exact transcriptions of what the child and the mother said (Mother: Mom & Boy: John).

### **Letter One**

The family read the letter quietly (**Problem Framing-a**). While neither Mom nor John talked about the letter and the proposed problem, they engaged in problem scoping through exploring material. The mother facilitated her son's engagement by asking him to find the pieces and what each piece does.

*Narrative 1: Mom and John start exploring the material. Mom looks at the kit guide that has named the pieces with their images and asks John to find each piece. Mom points to one of the pieces, and asks her son: "Do you know how we can use the tunnel?" John rotates the piece and then says, "I know how," and he grabs the gray base and demonstrates how he can use this piece (**Information Gathering-a**).*

### **Challenge One**

Challenge one was a well-structured building task. The child received a simple model of rollercoaster and was asked to build it using the provided construction kit. As was expected, we observed limited behaviors related to problem scoping. The child took the problem straightforwardly and started building it. However, after he started building, he realized some sub-problems that needed to be defined. The narrative below includes examples of problem scoping.

*Narrative 2. John and Mom look at the problem (**Problem Framing-a**). John loudly says, "I know how to do this," and then looks at the picture carefully (**Information Gathering-d**) and quickly grabs two black posts and places them on two sides of the gray base. Then, he starts counting how many black posts he needs for each tower based on what he sees in the picture (**Problem Framing-c**). After he builds the towers at both sides, he looks for the start and end track and choose them based on their color. After failing in attaching one, he rotates it and looks at the picture carefully and then at the pieces he has in his hand and he realizes he chose a wrong piece. He picks up the other two orange pieces, places them next to the picture and whispers, "here." He tries to attach them to the towers that the mom says, "correct just rotate it." Without saying anything, the child looks at the pieces again and rotates one and is able to attach it (**Information Gathering-a/b**).*

As seen in the narrative, John identified a criterion for his problem that the rollercoaster should be built with the exact pieces provided but also the same numbers of pieces. He engaged in information gathering as he carefully gathered information he needed to build the same roller coaster as the given model such as the needed pieces (e.g. same shapes and numbers) and exploring how each piece works with the other ones.

### **Challenge Two**

Challenge two was less well-structured than the first challenge, as the child was not given an image of the model. The challenge asked the child to build a roller coaster that is steeper than the other one. The challenge also directed the child by suggesting some pieces that he can try. We observed different behaviors of problem scoping exhibited by the child.

*Narrative 3. John reads the challenge (**Problem Framing-a**) and says Okay. He knocks down his previous model and keeps one tower. He quickly starts adding to the tower.*

*Mom: Do you know what you have to do?*

*John: Steeper (**Problem Framing-a/c**)*

*Mom: Do you know what steeper is?*

*John says yes and illustrates it with his hand. Mom then shows her arm and says it needs to have angle (**Problem Framing-c**).*

*John builds a high tower and a then a lower one and explores different slides to see which one can be attached to the two towers (**Information Gathering-a/b**) and he finally finds one that best fits. He tests it and the rollercoaster car falls off the track. Mom says, "why did it fall out, John?" John says, "oh, no, not safe," (**Problem Framing-d**) and he fixes the rollercoaster.*

As with the first challenges, John engaged in exploring what pieces he could use in his design. He also added context (and a criterion) to the design after realizing the coaster car can fall off. Keeping the car on the track was a sub-problem that came up after he tested his prototype version 1.

### **Challenge Three**

Challenge three was more ill-structured than the previous ones. The challenge provided an open-ended problem: "Build a rollercoaster that turns before it stops." During this challenge, we saw more evidence of the child engaging in problem scoping actions through conversation with his mom.

*Narrative 4. John reads the challenge, nods and then grabs two turn tracks and tries to connect them together (**Problem Framing-a & Information Gathering-a**). After some minutes of trying, Mom asks, "Do you think these two can go together?" John works with the pieces and then leaves them (**Reflection-a**). Then John grabs different slide tracks and sees which one can be attached to the turn track (**Information Gathering-a**). When he is able to attach a slide to a turn track, he builds a tower between the two he had from the previous model. Then he tries to connect them together using the attached turn track and the slide and with a couple of other pieces. He tries different pieces of the kit and then finally asks for help.*

*John: We need something to hold this [pointing to the slide that is attached to the turn track and should be attached to the middle tower].*

*Mom: I don't think this works this way, dude.*

*John: Never mind. This holds it (and leans the turn slides on the tower).*

*Mom: Turn it around, it is the other way round.*

*Mom hands John a different turn track. John looks at it, rotates it and replaces it with the other turn track. (**Information Gathering-b**)*

As John read the problem, he engaged in gathering information and framing the problem. He realized that he has to use turn tracks, then he explored how those turn tracks could be attached to other ones and how he could use them in his design. In addition, after Mom asks him a question about the two pieces he was trying to put together, it is possible that he engaged in evaluating the way these pieces could be used (evaluating how the supplied material work, see Table 1). Throughout the activity, he shows that he knows the problem and restates the criteria.

*Narrative 5. John builds the rollercoaster and tries it, but the car stops before it gets to the end. John says, "it counts, because it turns before it ends, it counts!" (**Problem Framing-a/c**). Mom agrees that he met the criteria for this challenge. However, he says, "No, wait, I have an idea." He removes some pieces and tries it. The rollercoaster car turns and stops at the end track.*

This is an example of the child restating the criteria of the problem, but also adding to it. Although he thought that his design met the specified criteria, he pointed to unspecified criterion that the rollercoaster should start at the start track and end at the end track and he found a solution for that.

### **Challenge Four & Letter Two**

Challenge four was when the child received the second letter from the director of the amusement park. The challenge was ill-structured and open-ended with three specified criteria and two constraints. The three criteria included: the rollercoaster should (1) start very high and end very low, (2) have one loop, (2) have one tunnel. Limited space and material are mentioned as constraints. In addition, at the end of the letter children are reminded of building a fun rollercoaster that is the steepest and fastest rollercoaster. At this point, children are expected to have explored the material and have ideas in mind for how to build the rollercoaster.

In this challenge, we observed many instances that the child engaged in problem scoping, and conversation and interaction with the mother increased.

*Narrative 6. Mom hands the letter to the John and asks him to read it aloud. He looks at the letter very briefly and says, "Challenge accepted! I know what to do." Mom then reads the letter and says, "Hey, they are asking you to start very high and end low." John says, "and a loop and a tunnel." (**Problem Framing-a/c**). While John is knocking down what he built in the previous challenge, Mom says, "John, all the posts have to be on this gray thing." John responds, "Ha, Okay" (**Problem Framing-a/b**).*

*Mom then asks, "John, do you have a picture in your head on you want to build it? You can also draw your idea, John." (**Problem Framing-a**) John, while trying to assemble the loop, responds "Mom, can you help me with this (assembling the loop)." (**Information Gathering-a & Problem Framing-a**).*

*Mom tries to assemble the loop, it seems to be broken. She tells the researcher that this piece is broken. Suddenly John says, “do you have a spare?” Mom says, “Even if they don’t, we will make this.” He responds, “No, it says a loop, we need a loop.” (Problem Framing-b/c). The researcher assembles the loop and returns it.*

We can see in this narrative, that the mother reads the problem and tries to explain the criteria to the child. The child shows that he is planning to consider them and even restates some of the criteria. He explores the loop and tries to assemble it to use it which also shows that he is considering the criteria; we consider this to be problem scoping rather than solution modeling because he seems to be engaged in exploring the problem criteria and materials available more so than creating a specific solution. He realizes the constraint of having only one loop and he also seems to know that without the loop he cannot solve the problem as it is one of his criteria.

*Narrative 7. Mom tells John, “Think about the rollercoasters we have been on, how do they work?” John responds, “They always go up first and should start very high. All go very high and then [go] fast. (Information Gathering-b, Problem Framing-c & Reflection-b). I have an idea.” He puts several black posts on top of each other (creating a very tall tower).*

The mother helps the child refer to their previous experience of riding rollercoasters and use that information for his design. The information he remembered is consistent with the criteria of the problem. This information seemed to help him reflect on his design solution by prioritizing the features in his solution. This was obvious in his conversation when he mentioned a rollercoaster “should” start very high and “then” go fast. We also see that right after this dialogue, he built a very tall tower, which probably indicates that he thinks that starting high is the most important feature of a rollercoaster.

*Narrative 8. A few minutes later, after few unsuccessful attempts, John gets frustrated and says, “I cannot do this, I can’t.” Mom affirms that he can, and says, “Let’s talk about it first and see how we want the rollercoaster to look like. Do you want it to start with a loop, you said?” (Problem Framing-a/c). John says, “I have an idea.” He gets engaged in building a new idea. After a few minutes of building and having conversation with Mom, his rollercoaster starts very high and comes down and has a turn track at some lower levels. John attaches the loop backward (down to up). Mom tells him, “do you think this works?” John says, “yes.” She then says, “Think if you have ever seen a loop in a park.” John, few minutes later says, “Like a giant slide?” Mom says, “Yes, this does look like a giant slide. Do you think that a giant slide can go down to up? It needs gravity, it can’t” (Information Gathering-b/c). John looks at the loop and tries the car in it which doesn’t move. He agrees and takes the loop out (Reflection-a).*

In this narrative, the child gets frustrated with designing his solution. Mom’s encouragement and soliciting input helped him to get back on track. She restated the goals her child had for the design which reminded him of the problem and criteria. Then, we can see that the son-mother conversation included some science principals that helped the child reflect on his use of given material which resulted in a different solution.

*Narrative 9. Towards the end and after a few rounds of building, testing and troubleshooting, John builds some small towers next to the track and says, “I know, it falls down. When it falls down, this keeps it. It is safe.” . Throughout the activity, Mom*

*and John restate the criteria several times. They also reminded themselves of the other criteria like it should be safe, or the car should go all the way through. (Problem Framing-c)*

## **Discussion**

In this study, we investigated problem scoping actions enacted by a 9-year old child with autism during an engineering design activity. The instances that we have seen in these mother-child interactions and conversation provided evidence that the child was capable of engaging in all three actions of problem scoping. The behaviors we observed were mostly associated with Problem Framing and Information Gathering. We had observed limited instances that could be associated with Reflection that primarily happened during the ill-structured challenge. In addition, although the aim of this study was not to examine parental influences on child's engagement in problem scoping, we noted that the mother played a stronger role as the activities became more ill-structured and open-ended. This was obvious through the amount of conversation between them.

The child engaged in problem scoping differently in different challenges. During the first challenge, the child's problem scoping was mostly limited to reading the task (problem statement) and exploring the materials. He also added a criterion of building the same rollercoaster as what he saw in the picture which was evidenced by him counting the number of pieces and making sure that the rollercoaster looked exactly like the picture. However, we could see that in the last challenge, with the help of the mother, the child restated the criteria many times, gathered information by making connections to his previous experiences and science knowledge, evaluated the way materials worked together and added context to the problem. In addition, problem scoping was investigated solely and not at the same time as other engineering design actions. However, following Watkins et al's suggestion [19], we ensured that instances we captured were the actions that happened with the connection to scoping a problem and developing a solution to the problem.

The process of engineering design is usually captured and taught in a cycle with sequential actions that may cause the misconception that design is a linear process. Problem scoping is typically the first action in that cycle and educators are encouraged to engage students in that action first (20). However, the findings of this study showed that the child did not naturally engage in problem scoping as the first design action. We observed that as the challenges were becoming more ill-structured, problem scoping was happening throughout each activity and in a non-linear order of engineering design actions. In well-structured activity (the first challenge) problem scoping happened at the beginning. However, in the final challenge which was an ill-structured problem, problem scoping happened as the child was working and building the solution. For example, on several occasions problem scoping happened after testing and troubleshooting; problem scoping helped with fixing the solution and generating new ideas and during the final evaluation. This finding is similar to findings from other empirical studies on design that show that children and adults engage in an iterative process during design and that problem scoping does not necessarily happen at the very beginning e.g. [7]&[9].

## **Conclusion & Implications**

In line with diversifying engineering education, we need to provide opportunities for underrepresented populations to be exposed to and practice engineering and engineering design.

However, to help children get the most out of these experiences, we need to design appropriate engineering activities while considering their needs and potentials. Since no engineering intervention has been designed and evaluated by research [33], we need to first characterize children with autism's engineering experiences, explore their strengths and weaknesses in relation to solving engineering problems and find out ways adults and peers can support them. As the first step to help neurodiversified engineering education, this study focused on one child on the autism spectrum and his mother. We have explored ways that he engaged in problem scoping. The aim of this study was not to compare children with autism and to children without autism, but to explore if and how children with autism can engage in engineering design.

In this study, we have observed many instances where the child with autism engaged in different problem scoping actions and behaviors. These instances highlight the capability of this child in scoping a design problem. Many of the instances captured in this study are similar to the ways children engaged in problem scoping in Watkins et al [19] and Dorie et al's [7] studies. We expect that the findings are not limited to this child and these series of activities and can be seen with other children with autism.

We believe that children with autism, with or without support of adults, need to be exposed to engineering design activities and need to have opportunities to practice their design skills and competencies across a range of well- and ill-structured problems. We believe that the structure of the series of activities that we designed for this child played an important role in the child's persistence in problem scoping and engineering design in overall. The series of engineering design challenges with the same theme varied in their structure helped the child to move away from spending too much time on spatially exploring the material and focusing on the main problem as the problem grew in complexity. Therefore, while further research is needed, we believe that similar series of activities may help children with autism engage in engineering design activity and be able to build their solutions.

In this study, we have observed challenges and moments of frustrations that the child faced, but with the support of the mother they were overcome. We have also seen moments that the child independently engaged in problem scoping and even initiated conversation about the solution with his mom. We argue that other children with autism may also face these challenges and exhibit these strengths which all should be supported appropriately by parents or educators. While this study is in its early phases, these preliminary findings shed light on the importance of developing appropriate design activities for this population where accommodations for addressing their needs are also considered.

### **Future Studies and Limitations**

Previous literature has compared behaviors of expert designers versus novice designers (of any age) during solving design problems [9, 20]. As an example, literature suggests that depending on the problem solver, a well-structured problem can be interpreted as ill-structured and many unspecified features can be examined to solve the problem [18]. In this phase of the study, however, our intention and aim was not to examine the similarities and differences of the child's behavior to novice or expert designers. Through our initial findings, we did not observe the child considering unspecified component of the problem during the first challenges, neither the mother facilitated more interpretation of the problem. However, given some similarities of instances enacted by the target child in this study with children of the same age in Watkins et al [9] study, we believe that children with autism may exhibit some expert behaviors when solving design

problem (like engaging in reflection). In future studies, we will consider conducting behavior comparison and we will examine the child's problem scoping behavior more in depth.

As mentioned above, we believe these series of activities helped the child to scope the problem and engage in the design activity and build his solution. Further studies should be conducted to explore child engagement in different types of well- and ill-structured design problems with short or longer narratives. To characterize engineering thinking of children with autism, we also need to focus on other aspects of engineering design. In this study, given the nature of the tasks, we observed that problem scoping was happening at the same time as modeling. We need to explore if we can draw a clear boundary between the design actions, or the behaviors can be associated to more than engineering design actions. In addition, to fully capture problem scoping of children with autism, future studies should be conducted to examine problem scoping (and other engineering design actions) in different settings and contexts.

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