Examining the Role of Parents in Promoting Computational Thinking in Children: A Case Study on one Homeschool Family (Fundamental)

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Examining the Role of Parents in Promoting Computational Thinking in Children: A Focus on Homeschool Families

Abstract

Computational Thinking (CT) is an often overlooked, but important, aspect of engineering thinking. This connection can be seen in Wing's definition of CT, which includes a combination of mathematical and engineering thinking required to solve problems. While previous studies have shown that children are capable of engaging in multiple CT competencies, research has yet to explore the role that parents play in promoting these competencies in their children. In this study, we are taking a unique approach by investigating the role that a homeschool mother played in her child's engagement in CT. This qualitative case study of a homeschool family is comprised of a mother and her six-year-old daughter. They engaged in two STEM+C activities designed by our research team. The parent first utilized the integrated STEM+C+literacy curriculum at home, and then visited a local science center. During their visit, both the parent and child interacted with an exhibit designed to promote engineering and computational thinking among children. Their engagement in both activities was video- and audio-recorded. Interviews regarding their experience were also conducted at the end of each activity (curriculum and exhibit participation). In this study, we employed a video analysis approach to examine child-parent interactions and utilized a thematic analysis approach to analyze the interviews. Our findings suggest that homeschool parents are integral to supporting children's understanding of CT.

Introduction

Engineering education at the pre-college level has risen significantly over the years. This increase in engineering education is supported by curricula, activities, and formal and informal learning experiences developed to promote engineering learning among young learners. This has led to research which continues to explore engineering learning of children in school settings with integrated STEM curricula, and in out-of-school settings with informal learning activities and science center exhibits. Many have also investigated the role that adults play in shaping engineering interest, promoting understanding of engineering concepts, and improving engineering skills. In fact, prior research posits that parents and teachers have substantial influence on supporting children's engineering engagement and promoting engineering skills. Hence, it is critical to explore how parents who choose to homeschool their children go about supporting their children 's engineering learning—especially given the upswing in the number of children being homeschooled in the U.S. over the past decade [1] [2], which is expected to steadily grow in the future. Thus, in this study we aim to investigate the role a homeschool parent plays in their child's engineering learning.

Literature review

In the last decade computers have become less of a cutting-edge technology and more of a commonality in every household. The shift in technology from exciting innovation to pertinent tools requires more than the ability to use computers for work. In fact, it is becoming increasingly pertinent for children to think like computer scientists and engineers. However, there are limited clear examples of what computational thinking looks like in K–12 education. Wing [3] suggests that computational thinking is broader than simply programming, and early experience with computational thinking can shape student attitudes toward STEM and computing for years to come. Computational thinking is a set of thinking skills and approaches that are needed to solve complex problems across different disciplines. CT involves thinking and processing information systematically and formulating problems and solutions in a way that can be carried out by an information-processing agent [4]. CT draws upon concepts that are fundamental to computer science, such as abstraction, algorithms, decomposition, logical thinking, and simulation. In addition, like engineering, CT relies on mathematics as the foundational knowledge to manipulate abstract structures using abstract methods [3][5].

Computational thinking is a core capability for most engineers as computational thinking competencies are a set of skills needed to transform real-life challenges into problems that can be solved with the help of a computer. CT skills also allow the problem solver to apply computer-based solutions to questions at hand. These commonalities between computational thinking and engineering can support seamless integration and foster ways of thinking that cut across multiple disciplines in education [6]. Moreover, CT and engineering can cultivate children's problem-solving skills and learning experiences can equip students with essential skills and knowledge necessary for the global economy [7]. However, these experiences not only need to span across multiple disciplines, but need to be introduced to children in traditional K–12 settings as well as homeschool settings. Homeschooling in the U.S has been on the rise over the past decade, and is expected to grow in the future [2]. This increase in homeschooling is due to several reasons, including unsatisfactory school environments, the desire of parents to provide religious and moral instruction not provided in schools, and dissatisfaction with academic instruction in schools [1] [8]. Given this growth in homeschooling, it is critical to explore experiences of homeschooled children.

There have been a number of studies on pre-college engineering that have investigated student learning in traditional school settings, including studies exploring children's engagement in computational thinking [e.g. 9–10]. However, homeschooled children have been overlooked by engineering researchers even though the number of students being homeschooled continues to rise in the nation [2]. On the other hand, while there is substantive literature that has explored the impact teachers have on students' learning in formal settings, research lacks in exploring children's engineering learning in out-of-school settings. This can be inferred from a recent systematic literature review on pre-college engineering education, which showed that fewer than 25% of the studies took place in out-of-school settings. Among this limited number only a few focused on children's learning and parental influence, and only one included homeschooled families [11].

A number of research studies support the notion that the influence parents have on their children's education begins as early as preschool [12–14]. Similarly, these studies highlight that parents are often said to be the first and best teacher a child has [12]. Consequently, we believe that understanding parental roles in a homeschool child's life is equally important as understanding teacher influences on traditionally schooled children. Understanding the experiences of homeschool children and their families can have far-reaching implications for engineering education, as homeschool parents follow an alternative approach and homeschooling is expected to continue to rise in the future [2]. In homeschool learning environments, such as science centers or homes, the experiences and activities tend to be more student-centered. Therefore, exploring the strategies that a homeschool parent implements to promote CT in her child can provide insights for other parents and teachers to teach engineering to their children.

Purpose of the study

This study is part of a bigger project in which we aimed to characterize computational thinking of children and uncover ways to promote their engagement in computational competencies [27]. In this particular study we explored the strategies that a homeschool parent employed to engage her child in CT during integrated CT+engineering activities. The research questions addressed in this study are:

> *What roles does a homeschool parent play that lead to their child's engagement in computational thinking during (a) an integrated literacy, STEM, and CT curriculum at home, and (b) interaction with an engineering and computational thinking exhibit in a science center?*

Methods

Research Design

This is a qualitative study that utilized a single-case-study approach to investigate the roles that a homeschool parent plays in promoting CT in her six-year-old child. We employed a case study approach because a 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" [15]. Case study analysis can be conducted using one individual case when in-depth and descriptive evidence is provided to interpret critical events [16]. In addition, in case study research, the investigation should be conducted in a specific context [15]. Previous studies in the field of STEM education and particularly engineering education have conducted single-case studies where they have defined their cases differently. For example, Stewart and Jordan [17] explored the experience of one single child during a robotic after-school program. In addition, Tsurusaki, Calabrese Barton, Tan, Koch, and Contento [18] explored the ways a science teacher leverages students' science content knowledge.

The phenomenon that this study explores is a parent's strategies that lead to a child's CT within the bounded system of one single homeschooling family (i.e. case). In this study, the family is being investigated across two different activities: one more structured (i.e. STEM+CT+Literacy curriculum) and one unstructured (i.e. engineering and CT exhibit). The findings of this case, along with the characteristics of the family and aforementioned activities, are discussed below.

Participants

Participants in this study consisted of a mother and her six-year-old daughter. This family was specifically chosen, as the mother teaches her child at home but had previously participated in an Educator Workshop (largely attended by teachers but also designed for homeschooling parents and informal educators) focused on STEM+CT integration. During the workshop, participants were introduced to the STEM+C+Literacy curriculum called PictureSTEM [28]. Therefore, the mom had knowledge about computational thinking competencies and was familiar with the PictureSTEM curriculum that was used in this study. Through the workshop, she also gained experience with other CT-related activities.

Context

The study was conducted in two different settings with two different activities. The first activity was conducted in the child's home, while she and her mom engaged in the PictureSTEM []. The second activity was conducted at a local science center, where the family interacted with an engineering and CT exhibit. The activities are described below.

STEM+C Integrated Curriculum

The *curriculum* was developed for students in grades K–12 to promote science, technology, engineering, and mathematics (STEM). The curriculum also bolsters literacy and computational thinking (CT) practices. Each curriculum unit consisted of a design challenge that prompted students to solve various engineering problems. For this study, the homeschooling family implemented the first-grade curriculum unit. In this specific curriculum, students utilized their problem-solving skills to engineer a solution to help solve a client's problem in the following scenario:

Perri is the owner of a pet store that sells a lot of different pet supplies to help customers care for their pets. The store sells pet food, leashes, cages, and habitats for dogs, cats, fish, birds, hamsters, and guinea pigs. The customers like the hamster habitat cages that are currently offered, but they have been asking for a way to expand the habitat cages so their hamsters can have more room to run and explore. The pet store owner elicits students' help by asking them to share their ideas on how to expand the hamster habitat.

Throughout this curriculum, students engage in the engineering design process, as they ask their client questions, help their client define the problem, and identify the criteria of the problem to be solved.

The unit has been developed purposefully to promote computational thinking, science, engineering, literacy, and mathematics connections (See Table 1- Appendix). Students create a habitat design as they engage in the engineering design process. To practice literacy skills, students engage in activities such as reading a story, making a topic map, and retelling the story through sequencing and prepositions to identify significant details in the activity. To practice mathematics skills, students describe and classify simple shapes and practice spatial reasoning as they rotate and combine shapes. For science skills, students learn about the needs of animals and how habitats can meet animals' needs. In terms of computational thinking, students follow and develop the algorithms and procedures. The unit consists of a total of 13 lessons: an introduction to the unit, six literacy lessons that are paired with six STEM lessons, and a wrap-up/closure activity.

Science Center Exhibit

Computing for the Critters is a science center exhibit designed to help children learn and use computational thinking and engineering thinking. It consists of several stations, each of which is meant to engage participants in different computational thinking competencies and engineering skills. The first section of the exhibit is a wall of instructions providing an introduction to computational thinking and the exhibit's task: participants must pretend to be a robot that will deliver medicine to three animals along the "quickest, easiest route" in an animal hospital (Figure 1). Immediately to the right of the instruction wall is a physical play structure. Children can enter the structure and climb between three levels, delivering colored balls to tubes labeled with each of the three animals. Robot costumes allow children to be further immersed in the role of a robot.

The children are meant to weigh the benefits of different paths through the maze-like structure, eventually choosing and "delivering the medicine" to the three animals along the optimal route. On a station separated from the rest of the exhibit, labeled "Plan It!" on one side and "Test It!" on the reverse, two-dimensional maps of the play structure can be used to plan and test a route before physically entering the structure. To the right of the play structure, the exhibit features a wall of descriptions of different engineering specializations. These descriptions include examples of ethnically diverse people who have utilized engineering skills in these specializations. In the center of this wall is a computer coding game fitting the theme of the rest of the exhibit: children are tasked with instructing an on-screen robot to navigate a hospital to reach the same three animals without colliding with any obstacles. Players must input a sequence of moves to navigate the environment and reach all three animals in a particular order, before pressing the "GO" button to watch the robot travel along the sequence of moves.

***Figure 1*. Computing for the Critters**

Data Collection and Analysis

The family was video- and audio-recorded during their engagement in both activities. The total length of the first activity (i.e. the STEM+C+ Literacy curriculum) was 484 minutes while the second activity (Science Center Exhibit) was 30 minutes long. However, for this paper, a total of 170 minutes of video recording of this family (i.e. 140 minutes of the curriculum and 30 minutes of interactions with the exhibit) was analyzed. For the curriculum, we focused on lessons 1B, 2B, 3B, and 4A because, based on the previous study that we have conducted [19], these specific lessons were more likely to engage students in CT than other lessons. The video recordings of the family allowed us to examine the child-adult interactions and conversations. We employed a video analysis approach suggested by Powell, Francisco, and Maher [20] to examine the videos. This model suggests seven non-linear phases for analyzing videos, including: *reviewing the video data*, *describing the video data*, *identifying critical events*, *transcribing*, *coding*, *constructing a storyline*, and *composing a narrative*. Since we had written a detailed description and narrative which included the dialogues, we skipped the transcribing phase.

The analysis of the data was divided among the authors, which was further divided into two groups. One group analyzed videos on implementation of the curriculum and the second group focused on videos of the exhibit. The intercoder reliability within the two groups was established by the lead author. In regard to the video analysis, each group first looked for instances when the child engaged in CT, and then explored if the parent played a role in this engagement. We focused on both interactions and conversations. To analyze the videos pertaining to CT, we used a CT framework that was previously developed by our research team after synthesizing existing models and framework for CT (Table 2–Appendix). This framework was then modified using research findings from the studies conducted in both formal and informal settings [e.g., 19]. Definitions of the competencies can be found in Table 2.

The analysis of parental roles was conducted using a framework capturing possible roles parents can play when engaging their children in CT activities [26]. This framework was previously developed by a member of our research team through review of literature surrounding roles parents play to promote scientific thinking of their children during visits to informal learning settings like museums [21-23]. Table 3 illustrates these roles, with descriptions and examples.

Findings

The findings reported in this work-in-progress study consist of analysis from the two main activities in which the family participated. First, we provide the findings from the implementation of the STEM+C+literacy curriculum. The findings from the analysis of the four curriculum lessons are organized by parent role (see Table 2). The second activity is the *coding* exhibit at a local science center. The exhibit findings are organized around the three elements of the exhibit. The findings of each activity are described separately to address the two parts of research question. For ease of reading, we refer to the child as "Rose" and the mother as "Mom".

PictureSTEM Curriculum Findings

In this study, we analyzed four lessons from the PictureSTEM curriculum. Throughout the activities, both Mom and Rose were involved in various STEM+C+literacy related tasks. For example, both engaged in exploring animals and in tangram activities that helped Rose understand the concept of 2D shapes (e.g., triangle, parallelogram) while designing the hamster habitat. Within the activities, various CT competencies were exhibited by both Mom and Rose. Consequently, Mom performed three main roles (*facilitation*, *encouragement*, and *co-learning*) to promote CT practices while engaged in the curricular activities.

Lesson 1B

Lesson 1B was developed to improve learners' understanding of different animals that live in specific habitats. One of the objectives of this lesson was to establish learners' interdisciplinary connections in science and engineering. The lesson allows children to sort animals based on their physical properties and basic needs, as well as to gather necessary information to define the problem and develop a new tool. In addition, this lesson was developed to meet the national standards (e.g., NGSS: K-2-ETS1-1, 4-LS1-1 [LS1.A]; CCSS-ELA: SL.1.1, SL.K.6).

Facilitation is one of the roles that we observed very frequently in this lesson. Through this lesson, Rose was engaged in identifying animals' physical properties such as fur, wings, and scales. During Lesson 1B (See Appendix–Table 1), Mom initiated the activity by posing questions to help Rose make connections to her prior knowledge. Mom *facilitated* the activity by relating characteristics of various animals. Mom placed the activity mat on the desk so that Rose could put each animal in its matching box. After Rose completed the activity, Mom said, "Tell me how you decided which animals went which boxes. How did you decide that?" In response, Rose stated, "Because I knew which one has furs, scaly, under ocean." Mom played a role to *facilitate* the work space and initiate the activity which resulted in Rose exhibiting an example of Pattern Recognition CT competency, as Rose recognized patterns among different animals.

Lesson 2B

Lesson 2B (See Appendix–Table 1) is developed to help learners build their understanding of animals' physical components and their basic needs, as well as how the animals interact with their specific habitats. This lesson engages learners in science and engineering design challenges, as they need to design a habitat for a hamster that accommodates its basic needs. Learners are engaged in a sorting activity that asks them to identify various animals and categorize their unique characteristics. This lesson also complements national standards (e.g., NGSS: K-2-ETS1-1, K-ESS3-1, 4-LS1-1 [LS1.A], 2-LS4-1; CCSS-ELA: SL.1.1, SL.K.6). In this lesson, we observed evidence of two roles: *Facilitation and Co-learning.*

Facilitation happened in multiple instances during this specific lesson. For example, when Rose was identifying each animal's basic needs and their specific habitat, Mom *facilitated* conversation with Rose. The following conversation resulted in recognizing patterns of animals and habitats:

> Mom: [It is an] animal [that] has fins, scaly skin, lives in an ocean, what animal is that?
> Rose: A fish.
> Rose: It is a type of cat, has a long tail, and it is a predator.
> Mom: Tiger.
> Rose: No
> Mom: Leopard
> Rose: No
> Mom: Lion
> Rose: No.
> Mom: I give up.
> Rose: [It is] a Cheetah.

Co-Learning was observed in various activities within this lesson and was occasionally exhibited by Mom in collaboration with Rose. During Lesson 2B, Mom and Rose collaboratively worked on developing an animal figure using tangram shapes. Rose utilized those shapes to create her animal. During this lesson, Rose was also asked to find a habitat for an iguana. This *co-learning* role resulted in Rose engaging in the CT competency of *Pattern Recognition*. As Rose recognized the shapes, she utilized those shapes to create her animal. The conversation that took place during this collaboration illustrates Mom's role in *co-learning*:

> Rose: Mama I know.
> Mom: Iguana lives in most hangs out in the ocean (sic).
> Rose: [when Mom was not convinced, Rose persisted to continue convincing her]...But it can hang out in the ocean too.. Mom…Mom…I know...[Marine Iguana] lives in the ocean too.

In addition, during this lesson, we observed another example of *co-learning* that resulted in *Pattern Recognition* CT competencies. Rose and Mom were developing the shapes using the tangram pieces, they were following each other's instructions as they were collaborating with each other.

Lesson 3B

Lesson 3B aims to establish learners' understanding of 2D shapes (e.g., triangle, square, and parallelogram). This lesson promoted learners' fluency in the shapes (e.g., triangle) to make different animals by using the tangram set. By increasing familiarity with the shapes, learners built their knowledge of algorithmic design and improved their spatial reasoning. This lesson also supports national standards (e.g., NGSS: K-2-ETS1-1; CCSS-ELA: SL.1.1, SL.K.6; CCSS-

Math: 1.G.A.1, 1.G.A.2). Mom played a role of *encouragement* that led to the CT engagement of Rose.

Encouragement was used by Mom as a way to engage Rose in CT. In most of the instances, we observed that Mom generally used verbal *encouragement*, but this mostly happened after Rose engaged in CT. As part of this lesson, Rose engaged in building animals using tangrams to develop her fluency, knowledge, and understanding of 2D shapes (e.g., triangle, parallelogram), while sorting given objects in the activity. Although Rose exhibited difficulty in making meaning out of the developed shape, Mom exhibited *encouragement* to reinforce Rose's engagement in showing both *Abstraction* and *Pattern Recognition* CT practices in the task. The conversation below illustrates Mom role of *encouragement*:

> Rose: It [the developed shape] looks kinda hard.
> Mom: It is ok, you can do it.
> Rose: But Mom… [After Rose turned the page upside down, she made meaning out of the shape] It is a dog.
> … [At further exploration]
> Mom: What animal is it?
> Rose: A cat.
> Mom: Look at how the square rotated. Do you see the rotation on?
> Rose: Oh yeah.
> Mom: Ok, very good. Awesome! Now you got a good start.

In this instance, Rose has identified patterns of the tangram shapes while sorting them to build the animals. In addition, Rose was able to abstract the animals by recognizing the main characteristics of the animals in the real world and associate them with 2D models.

Lesson 4A

In this lesson, L4A, learners were exposed to a sequencing activity through a story book, *Joey and Jet*. The story features a dog that goes through various steps to catch a ball. Accordingly, learners needed to make a set of steps that the dog followed in the story. One of the objectives of this lesson was to engage learners in computational thinking competencies (i.e., Algorithm and Procedures) by making a correct set of orders on a flowchart provided in the lesson. This lesson also aligns with national standards (e.g., NGSS: K-2-ETS1-1; CCSS-ELA: SL.1.1, SL.K.6, RL.1.7, L.1.1.I; CSTA: 1A-A-5-3).

Encouragement was the role used by Mom to engage Rose in CT. During this lesson, Rose was asked by Mom to complete the actual steps that the dog followed in the story. Through this activity, Mom encouraged Rose to develop the correct steps without using the story book. As a result of this involvement, Rose exhibited *Algorithms and Procedures* CT competencies. The following transcription indicates Mom's role of *encouragement*:

> Mom: We are going to retell the story of Joey and Jet by using the cards. Let's try without the book first. What do you think arrow means?
> Rose: How it goes.
> Mom: Right, the direction of the sequence.
> …[After Rose completed the sequencing]

Mom: So what does he (Jet) have to do to get back to Joey?
Rose: Do it all backwards.

Co-learning was another parental role that resulted in Rose engaging in CT practice. During the L4A activity, Rose was engaged to place the propositions on the card correctly. We observed that Mom collaboratively worked with Rose, and at the same time, provided the necessary tools (e.g., cards that had pictures from the story) to involve Rose in showing Pattern Recognition and Debugging/Troubleshooting CT competencies. The following conversation provides the context of parental co-learning and facilitation roles:

Mom: Tell me some of these. Let's look at these [cards]. We are going to put in propositions up on the top of the cards.
Rose: [Rose is looking at the cards for the right propositions]. Down the hole.
Mom: OK. So this is down the hole. [Mom is writing the proposition given by Rose on the card].
Rose: [Rose is sorting the cards to find the next proposition on the right card]. Out [of] the hole.
Mom: Hmmm… [Mom corrected Rose by stating "Out *of* the hole"]
...Rose continues to look for other cards to find the right propositions.
Rose: In the trees… Over the water [Rose was not sure about the right proposition and wanted to confirm it with Mom. However, Mom was not sure either. Therefore, Mom needed to confirm the right proposition by looking at the story sequencing in the book]
Mom: Let's see…Let's go back in the story…Let's see what happened. [Mom found the correct proposition]. On the water.
Rose: On the water. [Rose realized her mistake and corrected it by stating the right proposition (Debugging)].

Overall, these examples display the various ways parental roles influenced the homeschooled child's learning of CT.

Exhibit

As described before, the exhibit included different activities for visitors. These activities involve pretending to be a robot delivering medicine to animals in a play structure, planning and testing a solution through a hands-on 2D maze, and finally playing with a computer-based coding game. After analyzing and coding the videos of this family during the exhibit activities (Play Structure, Plan It!/ Test It!, and Computer Game), we observed that Mom adopted multiple roles which facilitated Rose's engagement in CT. Throughout the various activities, the roles we observed included: *Supervising/Directing*, *Facilitation*, *Co-learning*, *Student of the Child*, *Encouragement* and *Disengagement* (see Table 2 in the Appendix for definitions and examples).

Activity 1. Immersive Play Structure

The family spent limited time exploring this activity, which mostly required freely exploring the animal hospital play structure. Mom did not read the instructions; therefore, Rose was freely playing rather than attempting to find the "quickest, easiest route" for the robot to deliver the medicine. This resulted in observation of no CT engagement by Rose nor any roles played by Mom to engage Rose in CT.

Activity 2. Plan It!/ Test It!

During this activity, Mom and Rose planned the problem using a 2D maze, where they counted the number of moves required for the robot to deliver the medicine to each animal. Mom and Rose worked together to find the shortest route for the robot to reach the animals. Mom played two roles during the Plan It! activity that resulted in Rose's engagement in CT: *facilitation* and *directing*. Both of these roles were observed while Mom and Rose were engaged in data collection, which involved counting the numbers of steps to get to a specific animal. The ways Mom engaged in *facilitation* and *supervising*/*directing* are illustrated in the narrative below.

Facilitation. The role that Mom engaged in most frequently during the Plan It! activity was *facilitation*. Mom engaged in this role in a variety of ways, which resulted in Rose engaging in multiple CT competencies. *Facilitation* mostly led to Rose engaging in data collection. One example was when Mom asked Rose questions, prompting her to think in a specific way. Mom asked, "From the rabbit, how many moves would it take to get to the dog?" This led Rose to count the number of spaces to the rabbit. Rose thus gathers information and engages in data collection to solve the given problem. This engagement in CT was the direct result of Mom's role of *facilitation*.

In another example, *facilitation* occurred when Mom made suggestions as Rose was engaging in the activity. For instance, Mom prompted Rose to find the fastest route to the cat. Rose in turn counted the number of steps to the cat along various paths. During this interaction, Mom also facilitated data collection (i.e., gathering information to find the fastest route).

Supervising/directing. Additionally, another role Mom played during this activity was *supervising/directing*, which occurred when Mom requested that Rose act in a specific way. For example, Mom asked Rose to "compare different ways that takes the robot to the cat." This prompted Rose to count the number of steps to the cat along the various paths and choose a path accordingly. Mom's role prompted Rose to engage in data collection.

Activity 3. Computer-based coding game

In the computer game activity, Mom and Rose had to code the robot to find the quickest and easiest route possible for delivering the medicine to the animals. The computer-based coding game consisted of a tutorial and five levels which Mom and Rose worked on together to complete.

The findings from the video analysis demonstrate that Mom played multiple roles to foster Rose's engagement in computational thinking. We observed that the parental role of *facilitation* led Rose to engage in the CT competencies of Pattern Recognition, Algorithm and Procedure, Abstraction, Debugging, and Simulation. Also, we observed that *co-learning* allowed Rose to engage in the CT competencies of Algorithm and Procedure and Debugging. In addition, *supervising/directing* also led to Debugging. However, in some instances Mom's disengagement led to Algorithm and Procedure, which will be discussed later.

Facilitation was the most observed role in this activity. *Facilitation* occurred when Mom asked Rose questions to encourage her to think in specific ways. For example, when Mom and Rose started a new level of the game, they realized there were some additional blue lines for the robot. Mom asked, "What do you think these blue things are?" (*facilitation*). Rose responded, "Umm, walls?" (Abstraction). In another situation abstraction is observed when Mom questioned, “Can the robot go through the walls?” In her response, Rose suggested, “Nope, they cannot” (Abstraction). This caused Rose to delete all of her code to fix the error (Debugging) and re-enter new instructions (Algorithm and Procedure). In these examples, Mom used *facilitation* to engage Rose in CT competencies of Abstraction, Debugging, and Algorithm and Procedure.

Additionally, parental *facilitation* fostered Rose to utilize Algorithm and Procedure. During one of the levels, Mom prompted Rose to get to the cat, without telling Rose how she should proceed. This caused Rose to input specific code that would help the robot reach the cat from the starting position.

Another example of parental *facilitation* was observed when Mom made suggestions to Rose. Mom told Rose “you need to move to the cat, then the dog, then the rabbit,” motioning between them with her finger.

Similarly, Mom also *facilitated* by breaking the problem down for Rose (Problem Decomposition). In one case, Mom asked, “So how are you going to get to the cat? …Now the cat to the dog? … Now the dog to the rabbit?” As Mom posed questions, Rose entered the directions the robot must follow to get between the animals, therefore engaging in the CT competency of Algorithm and Procedures.

Supervising/directing was another parental role quite visible in this activity. This occurred when Mom asked Rose to act in a specific way. In one instance, Mom directly showed a problem to Rose and told her how to fix it, by stating “go back.” Rose then deleted the entire series of instructions and followed Mom’s instructions, resulting in enactment of the CT competency of Debugging.

Co-learning was also observed during the activity when both Mom and Rose worked together to complete a task. Co-learning occurred after Rose identified an error in her code (Debugging). Rose deleted all of the code. This was followed by Rose and Mom collaboratively adding new code. During this situation, Rose and Mom had a short discussion on how they could fix the error. Mom then simulated where the robot would go, while Rose gave directions to Mom. Here we observed that Rose participated in the CT competency of Debugging and Algorithm and Procedure, as Mom and Rose worked together to solve the task.

Disengagement was observed when Mom left Rose to complete a task on her own. For example, Mom told Rose that “she is on her own for level three.” This caused Rose to enter code on her own to solve the problem. The parental role of *disengagement* is clearly displayed here, which in turn prompted Rose to enact the CT competency of Algorithm and Procedure.

Discussion

In this study, we have explored the roles that a homeschooling parent played during CT-related activities which resulted in the child’s CT engagement. To do so, we examined parent-child interactions and conversations across two main settings: a science center and their home.

The child exhibited CT competencies in several instances, some of which were elicited by the role the parent played. These competencies and their parental influence were observed during the exhibit activities and curriculum activities. In analyzing data from the curriculum, we chose to focus on the four lessons that were designed to promote CT competencies. On the other hand, the science center exhibit was specifically designed to promote engineering and CT.

Therefore, we were able to observe more parent-child interactions related to CT competencies in the videos from the science center, in which the parent played an influential role.

As indicated in the findings, *facilitation* was the most observed role in both exhibit and curriculum activities. *Facilitation* occurred through questioning and suggestions, resulting in the child's engagement in various CT competencies, including Data Collection, Debugging, Algorithm and Procedure, and Abstraction. During the curriculum activities when the parent played the role of *facilitation*, it helped the child visualize Patterns and Decompose the Problem. This demonstrates that in both formal and informal settings, *facilitation* is integral to motivation and engagement. Parental *facilitation* can foster a child's interest in STEM+C disciplines and enable a homeschooled child to engage in CT competencies [24].

Another important role that was evident in both exhibit and curriculum activities was *co-learning*. *Co-learning* happened when both the parent and the child tried to solve a problem simultaneously, with neither leading the activity. This role was particularly observed during the computer-game activity, which resulted in the both the child and parent identifying the problem in the code/algorithm (Debugging), simulating the solution (Simulation) and creating a new algorithm (Algorithm and Procedures). *Co-learning* was important as it helped the child stay focused on the task and learn through collaboration. This collaboration between parent and child allowed the child to enact various competencies without showing any frustration or losing interest. The mentorship the parent displayed during the parental role of *co-learning* was necessary for the homeschooled child, as it resembled a peer-to-peer collaboration often seen in informal learning environments.

Finally, the parental roles of *disengagement* and *encouragement* occurred in different activities (exhibit and curriculum) and were important for the child's growth. The parent *disengaged* herself during the exhibit activity to allow the child to progress individually to the higher levels in the game (level three). This was done after the parent had *facilitated* the learning up to that level. At this point the child was already engaged, so she was able to continue to make progress and develop her own algorithm to solve the problem. During the curriculum activities, the parent used the role of *encouragement* as the child enacted the CT competency of Pattern Recognition, supporting the child's progress in the curriculum activities.

While each role is unique, they all serve to support a child's engagement in CT competencies. The diversity of roles demonstrates an important aspect of parental support and influence in a homeschooled child's learning [24]. There are many different ways to support children in a homeschool setting, and these are just a few observed in our study that led to the child's understanding of the various CT competencies. The figure below (Figure 2) illustrates how parental roles fall in a hierarchy of involvement.

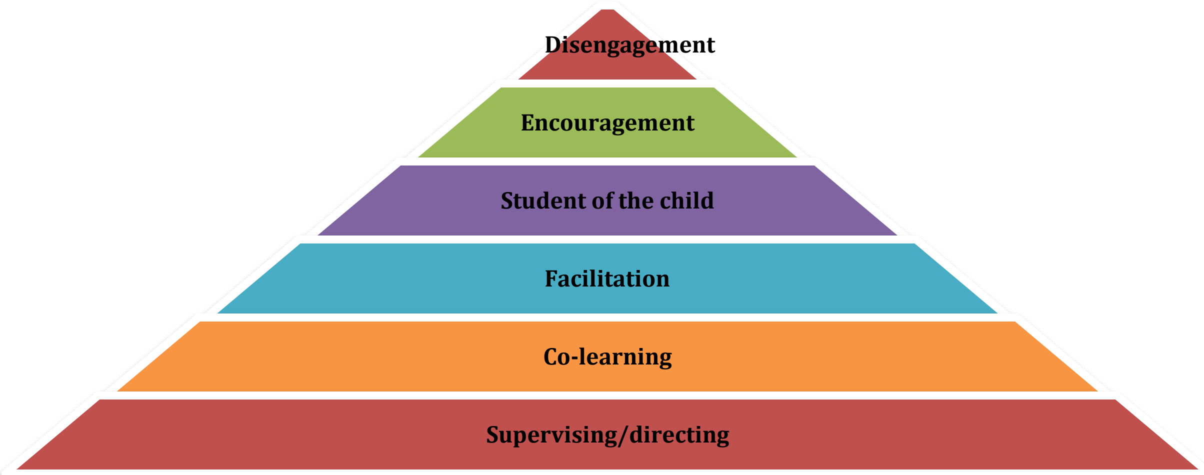

Figure 2. Parental roles engagement level.

The role at the bottom of the pyramid, *Supervising/directing*, is associated with the greatest amount of parental involvement. This level of parental involvement limits the child's freedom to make decisions. By contrast, at the top of the pyramid, where the parental role shifts to disengagement, parents provide a space for the child to feel more empowered to do the activity independently. We believe that this shift in parental roles from level to level is necessary, as the child gradually feels more confident with the activity. The parent provides necessary scaffoldings to support the the child's learning and growth. This level of hierarchy pertaining to parental role and its impact on child learning is supported by the Vygotsky's *zone of proximal development* [25]. Here the learning is a combination of the other (parent) and the environment, which helps to create new knowledge. We can see in this study that parents' *facilitation* created many productive moments for the child to engage in CT. Through this role, the parent supported the child's engagement and learning by asking questions and prompting the child. However, as the child progressed in levels of the video game or practiced activities like tangrams, other parental roles also became productive and important. Therefore, we are not suggesting that other roles do not play a role in children's engagement in CT. However, we believe that children need to be supported throughout CT activities. The level of parental engagement can decrease overtime as the child gets more familiar with the coding activity.

Another reason various parental roles were observed in these two contexts was the nature of the activities. The exhibit activity required the parent to switch between roles more so than when the family was interacting with the curriculum. For example, in situations at the science center, the parent's role was supervising the activity and directing the child on what to do. However, there were also times that the parent either *disengaged* from the activity or collaboratively engaged in computational thinking to help solve the problem. During the curriculum, the parent mostly *facilitated*. This is primarily due to the structured nature of the curricular activities, which required more support and parental engagement, as compared to the exhibit activities, which were designed for self-directed learning and were open-ended.

Conclusion and Implications

In conclusion, parents play an important role in their child's education, development, and attitudes. As demonstrated in this study, the various roles the mother played helped to support her child's engagement in CT competencies. Though each contribution from the mother was unique, it served one purpose: to foster the child's understanding of CT. The diversity of roles captured in the parent-child interactions illustrate an important aspect of the parental influence in the homeschooled child's learning [24]. The homeschooling family in this study highlights the importance for the engineering community to remember this population when conducting engineering education research. More importantly, a better understanding of the interaction that takes place in a homeschool environment can guide development of children's engineering knowledge and skills in out-of-school settings.

This study adds to literature on homeschooling and engineering learning, an area that is underexplored in engineering education. The findings of this study stress the importance of parental roles in supporting the learning of children in both parent-led and child-led activities. While there is significant literature that explores parental influences on child learning in formal and informal settings, there is a lack of research involving homeschooled children. The findings from this study can support an understanding of the various roles that parents can play, and how these roles can foster CT competencies among young and homeschooled learners. In turn, it can help to develop resources and experiences that support the parent of a homeschooled child. These experiences could include parental workshops that not only focus on curricular content but also assist with developing strong parent-child interactions; for example, seminars for parents on new ways to bond with and teach their children. However, the results of this study are limited to describing a phenomenon rather than predicting future behavior.

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Appendix

Table 1. Focus areas of the integrated STEM+C curriculum (PictureSTEM) (included lessons in this study are highlighted)

Lesson	PictureSTEM Focus Areas
Introduction	*Engineering:* Asking questions and gathering information to define a problem about a situation people want to change through developing a new tool.
1A	*Literacy:* Identifying, organizing, and recording important facts or information from the text. *Science:* Identifying hamsters by their physical characteristics and mention their basic needs drawing from information in the literacy books.
1B	*Science:* Sorting animals based on their characteristics and basic needs. *Engineering:* Asking questions, making observations, and gathering information to define a problem about a situation people want to change through developing a new tool.
2A	*Literacy:* Making connections from one part of the text to another. *Science:* Using knowledge about how the physical characteristics of animals influence their choice of habitat.
2B	*Science:* Sorting diverse living things by many different observable characteristics. *Science:* Identifying where animals get their basic needs in their habitat, which is a natural system that has many components that interact to maintain the system.
3A	*Literacy:* Answering questions about what they are reading to promote understanding. *Mathematics:* Describing basic shapes, 3-sided (triangle), 4-sided (quadrilateral), and 5-sided (pentagon). *Mathematics:* Identifying differences among various shapes and associate them with the correct names.
3B	*Mathematics - Spatial reasoning:* Rotating, flipping, and sliding 2D shapes in order to combine them to create new shapes

4A	*Literacy:* Using prepositions to describe actions. Using flowcharts to organize the sequence of events in a story. *Computational Thinking - Algorithms & Procedures:* Sequencing the events of the story using a flowchart.
4B	*Mathematics:* Composing 2-D shapes to create composite shapes. *Computational Thinking - Algorithms & Procedures:* Following and creating algorithms.
5A	*Literacy:* Identifying new vocabulary words ("juicy" words) and use strategies for determining the meaning of those words. *Engineering:* Discussing the importance of testing materials before building a prototype.
5B	*Engineering:* Testing materials, determining the best materials to use and plan the designs before building and testing them.
6A	*Literacy:* Identifying important details that will help to summarize the story.
6B	*Science:* Describing how an animal's habitat provides for the basic needs of that animal. *Engineering:* Testing prototypes to be sure their designs meet the hamsters' needs. *Engineering:* Redesigning the prototype when designs could be made better or fails; redesign is an important part of engineering.

Note: The highlighted lessons were analyzed for CT competencies.

Table 2. Computational Thinking Competencies

CT Competency	**INSPIRE Definitions**
Abstraction	Identifying and utilizing the structure of concepts/main ideas
Algorithms and Procedures	Following, identifying, using, and creating an ordered set of instructions (i.e., through selection, iteration and recursion)

Automation	Assigning appropriate set of tasks to be done repetitively by computers
Data Collection	Gathering information pertinent to solve a problem
Data Analysis	Making sense of data by identifying trends
Data Representation	Organizing and depicting data in appropriate ways to demonstrate relationships among data points via representations such as graphs, charts, words or images
Debugging/Troubleshooting	Identifying and addressing problems that inhibit progress toward task completion
Pattern Recognition	Observing patterns, trends and regularities in data (Google)
Problem Decomposition	Breaking down data, processes or problems into smaller and more manageable components to solve a problem
Parallelization	Simultaneously processing smaller tasks to more efficiently reach a goal
Simulations	Developing a model or a representation to imitate natural and artificial processes

Table 3. Parental Roles

Role	Leader	Definition	General Examples
Supervising / Directing [2],[3],[4]	Most Adult-led	Parent directly instructs child to act in a specific way.	"You guys do the same path in there. So you've gotta go to your right"

Facilitation [3], [4]	Adult-Led	Parent makes suggestions and prompts the child to think in a specific way.	"Do you not think that would have been quicker if you went to red first?"
Co-learning [4]	No leader	Both parent and child work together on a task together; neither is the leader and no prompting occurs. Parent and child share information with each other.	Parent shows the current location of the robot in the game while the child enters instructions "Oh, these are walls!"
Student of the Child [3],[4]	Child-led	Parent prompts the child to take the lead in the activity.	"So we know that you got the cat. Now what?"
Disengaged	Most Child-led	The parent completely disengages from the activity, leaving the child to continue on their own.	"The mom says 'Do what you want.' and she steps back"
Encouragement [4]	Ancillary	Parent reassures or encourages the child while they are working on a task or after they complete a task.	"Awesome!" "You found the best answer"