Education Development Center

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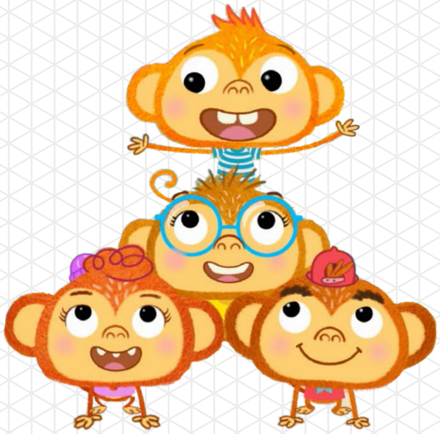
Computational Thinking with *AHA! Island*

Supporting Joint Media Engagement Between Children and Parents



ABOUT EDC

Education Development Center (EDC) is a global nonprofit that advances lasting solutions to improve education, promote health, and expand economic opportunity. Since 1958, we have been a leader in designing, implementing, and evaluating powerful and innovative programs in more than 80 countries around the world.

ABOUT WGBH

WGBH enriches people's lives through programs and services that educate, inspire, and entertain, fostering citizenship and culture, the joy of learning, and the power of diverse perspectives.

ABOUT *AHA! ISLAND*:

AHA! Island is an NSF-funded research project that aims to bring computational thinking concepts to preschoolers and their parents through joint engagement in media and hands-on activities.

ACKNOWLEDGEMENTS

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Introduction

Project Overview

Computational thinking (CT) is a creative way of thinking that empowers children to be systematic problem-solvers, enabling them to identify problems and then brainstorm and generate step-by-step solutions that can be communicated and followed by computers or humans. CT has been identified as beneficial for improving student achievements in STEM, literacy, and other disciplines (Wing, 2011). It also helps students move beyond memorization and toward deeper learning that transfers from one situation to another (Grover & Pea, 2018; Pellegrino & Hilton, 2013).

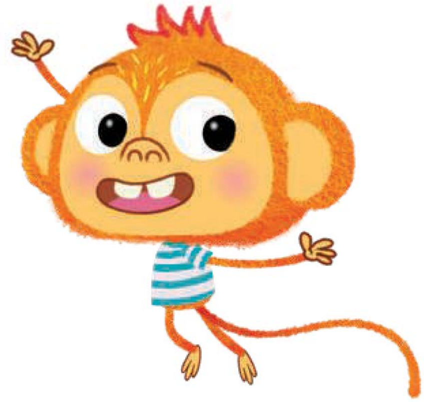
While CT has been integrated into middle and high school curricula, particularly in the area of computer science, little is known about how best to support the early development of young children's CT skills. Existing literature suggests that young children are quite capable of engaging in many skills involved in thinking computationally. Recent work indicates that children as young as four years old can develop CT knowledge around sequencing, repeat loops, setting parameters, and creating conditional commands (Bers, 2008, 2010; Portelance & Bers, 2015; Strawhacker & Bers, 2015). Wyeth and Wyeth (2001) found that children between the ages of four and six were able to use electronic "blocks" to build robots and remote-control cars. Further, research shows that learning to code at a young age can positively affect children's sequencing skills in both laboratory and classroom settings (Kazakoff & Bers, 2010, 2012, 2014; Sullivan & Bers, 2015).

Much of the research referenced above focuses on children applying CT in developing their programming skills. However, the approach of the current project, *AHA! Island*, is to broaden the use of CT among young learners by supporting the development of CT-based problem-solving strategies, consistent with those used in computer science in the upper grades but also relevant to any number of real-world problems.

AHA! Island aims to foster joint media engagement around CT among low-income 4- to 5-year-old children and their caregivers (hereto referred to as "parents"). WGBH and Education Development Center (EDC) have partnered to engage in the iterative development and testing of *AHA! Island* resources (i.e., animated stories, music videos, live-action videos, hands-on activities, and supports for parents and educators) as an intervention to support preschool CT learning in nonprogramming contexts. Through this project, the research and development teams seek to accomplish the following:

- Develop CT learning goals for young children
- Explore strategies for introducing CT concepts to young children through videos and hands-on activities
- Investigate how certain learning tasks can demonstrate what children understand about CT
- Identify ways to support parental involvement in children's CT learning experiences

As such, *AHA! Island* constitutes pioneering work in the field of early STEM learning. The program uses an iterative research and development process to build new knowledge about appropriate CT learning goals for children; strategies for introducing CT to children through joint engagement in videos and hands-on exploration; and the ways in which CT learning can be measured, enriched, and deepened with young children and their parents at home through successive experiences. Ultimately, this research will contribute to the field's knowledge regarding young children's acquisition of CT skills and the scaffolds necessary to increase parents' capacity to support early CT learning.

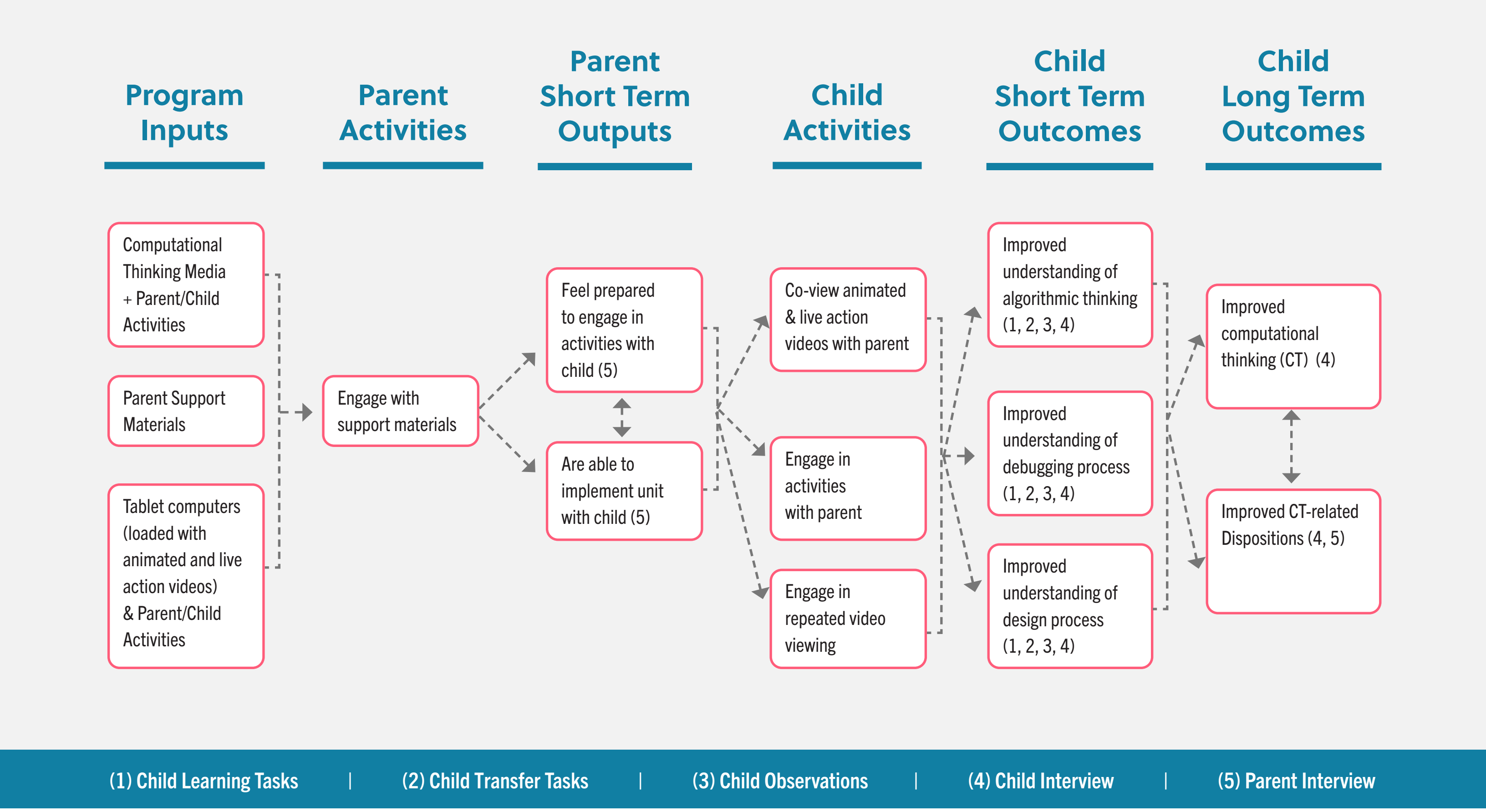


Background

Theoretical Framework

The design of the *AHA! Island* joint engagement intervention rests on the assumption that, with the right supports and scaffolds, parents can learn about and implement practices that support young children's CT learning at home. The initial design and development of the project's logic model was based on theory and research about effective parent engagement strategies through scaffolding and media. The logic model, presented in Figure 1, outlines the hypothesized process for how the model intends to accomplish short- and long-term outcomes in children.

Figure 1. Logic model for short- and long-term outcomes



The Intervention: *AHA! Island*

The *AHA! Island* intervention consists of a collection of videos and hands-on activities related to the following Core Ideas of CT: algorithmic thinking, debugging process, and design process. The intervention also includes parent support materials containing background on each CT Core Idea and an outline of the recommended six-week model and suggested sequence for how families can explore the materials together. The videos use a combination of animation and live-action videos of children and their parents engaged in modeling CT practices. The music videos feature short animated stories focused on characters modeling the use of CT skills to solve problems and songs to reinforce CT-focused problem-solving. In addition to supporting children's exploration of these skills, the materials focus on fostering parent confidence when exploring these topics during hands-on activities with their children.

Research Questions

The purpose of the impact study was to assess the value of *AHA! Island* videos and hands-on activities in supporting CT skills of young children. The *AHA! Island* study focused on addressing seven research questions:

RQ1 To what extent are the *AHA! Island* parent-child engagement resources (videos, hands-on activities, parent supports) useable and appealing to parents?

RQ2 What evidence exists that the resources, when used during co-engagement between parent and child, promote CT skills and dispositions, including testing and iterating, tolerating ambiguity, persistence, and curiosity in children?

RQ3 What factors work together to support or impede effective use of the parent-child engagement resources?

RQ4 Are preschool children that experienced video and engagement with their parents better able to apply CT Core Ideas (algorithmic thinking, debugging, and design process) relative to children in the control group?

RQ5 Does the use of parent-child engagement resources increase parents' interest and comfort in engaging in hands-on activities in which preschool children apply their CT?

RQ6 Do parents who use parent-child engagement resources report that CT becomes more of a habit of mind in their children's daily lives?

RQ7 Do 5-year-old children that participated in the *AHA! Island* intervention demonstrate enhanced CT knowledge that transfers to a programming environment?

KEY DEFINITIONS

Several key terms are used throughout this report. Definitions for these terms are as follows:

Computational Thinking: A creative way of thinking that empowers children to be systematic problem-solvers, enabling them to identify problems and then brainstorm and generate step-by-step solutions that can be communicated and followed by computers or humans.

CT Core Ideas: A set of developmentally appropriate skills that prepare children for computational thinking later in life.

CT Catchphrase: An easily-understood phrase that can be used to refer to certain CT Core Ideas (e.g., "step it out" for sequencing; "make it work" or "check your steps" for debugging; and "create, test, improve" for the design process).

CT Dispositions: A set of attitudes and behaviors (like persistence and curiosity) that support the systematic problem-solving approach used in CT.

INTERVENTION COMPONENTS

Several different types of resources were included as part of the *Aha! Island* intervention. Each component is briefly described below.

Videos

Three different digital video formats were developed to support joint engagement around CT skills.

1. **Animated Stories:** These videos ran about 6 minutes on average and focused on a set of characters exploring a problem and using different CT Core Ideas to generate and implement solutions. For example: Fred, Maisy, Daisy, and Bo make lemonade, but Mr. and Mrs. Flamingo think it's too sour. The monkeys use a debugging process to check their steps to figure out what they need to do to improve the taste of the lemonade.
2. **Live Action Videos:** These videos, averaging 3 minutes, depict children and families engaging in explorations that use CT Core Idea strategies in the real world. For example: Children play a game with their dad, who pretends to be a robot who wants to make a peanut butter sandwich. He follows their directions very literally, showcasing the importance of creating a set of ordered directions that is clear and unambiguous.
3. **Music Videos:** These short videos, averaging 90 seconds, focus on presenting CT Core Ideas in the context of catchy fun songs. For example: The monkeys want to enter a go-kart race, but they need to figure out how to improve their kart's design. As they make changes using the design process, they sing, "Now we're in the groove: create, test, improve!"

Hands-on Activities

For each of the featured CT Core Ideas (sequencing, debugging, design process), families received hands-on activities to practice exploring the concepts in real-world ways. An example of a hands-on activity for each CT Core Idea follows:

- Sequencing: **Mixed Up, Dress Up** – Children and parents play a silly game and use clothing cards to create a sequence for getting dressed.
- Debugging: **Create Sound Shakers** – Children and parents create sound shakers by placing household materials in small containers. The parent intentionally makes a shaker that doesn't make much noise (e.g., filling the shaker with cotton balls) and asks the child for help in making it louder.
- Design Process: **Design a Bridge** – Children and parents use household materials to create a bridge that will enable a toy car to travel across a sink or basin of water. Then they test and improve their bridge.

Parent Supports

The intervention was also supported by parent handouts that explained each of the CT Core Ideas with a definition and ways to practice these concepts in everyday activities with their preschool child.

Method

Design

The EDC research team conducted the study between February and May 2019 with families recruited from 12 early childhood education centers in New York, Massachusetts, and Rhode Island. During this study, two groups of low-income families (intervention and control), who were fluent in English, used a set of videos and hands-on activities at home for a six-week period. The families in the intervention group received *AHA! Island* videos and hands-on activities designed to support CT skills. Researchers provided control group participants with a comparable set of videos and hands-on activities that were not focused on CT or STEM education. The videos combined the use of animation and live action to support the literacy, and specifically vocabulary, of children in early childhood. The activities, like those from the intervention, were hands-on and play based, but they did not support the exploration of problem-solving activities. The goal for the control group participants was to mimic the overall amount of parent-child interaction in the intervention group. The key difference between the control and intervention groups was the time spent focused on the development of CT skills.

During a series of initial onboarding meetings, researchers did the following:

- Provided both intervention and control group parents with an overview of participant expectations
- Asked parents to only use materials from their assigned condition, to not switch tablets with other participating families, and to request support for any technical difficulties with their tablet by calling a technical support phone number
- Reviewed the contents of the take-home study packages, which included the tablet (loaded with videos and digital versions of the hands-on activities), a folder with printed copies of the hands-on activities, and the handout that provided guidance on how to access all study materials

Participants were not provided guidance on the educational focus of the intervention or the educational goals of the intervention materials. All participating parents responded to pre-surveys about their family's learning habits and their notions about CT, if any.

After the six-week period, researchers visited a subsample of participating children at their early childhood education centers to conduct a maximum of five hands-on assessments (four learning tasks and one transfer task[1]). During parents' off-boarding meeting, researchers also conducted post-surveys with all parents. At a later date, researchers conducted phone interviews with randomly selected volunteer parents from the intervention group about their experiences using the study resources.

1 Children from the intervention and control groups participated in the learning tasks. However, only children from the intervention group participated in the transfer task.

Sample

A total of 108 families, recruited from 12 urban early childhood education centers in New York, Massachusetts, and Rhode Island, participated in the impact study. Of the 108 families, 54 participated in the intervention and 54 in the control group. The sample of families was ethnically diverse across both groups. The majority of participating caregivers were mothers (83% for both intervention and control groups), with smaller percentages of fathers (11% intervention, 9% control) and grandparents (6% intervention, 8% control). The Appendix: Study Design and Sample Characteristics shows the sample distribution in more detail.

Below, we present a description of the participating sample.

- 30% of the intervention group and 41% of the control group identified the participating child as Black or African American.
- 28% of the intervention group and 18% of the control group identified the participating child as Hispanic or Latino.
- 15% of the intervention group and 6% of the control group identified the participating child as White (Non-Hispanic).
- 13% in each group identified the participating child as Asian.
- 9% of the intervention group and 18% of the control group identified the participating child as biracial.
- 5% of the intervention group and 4% of the control group identified the participating child as Other race.

In terms of socioeconomic background, the majority of the sample (70% intervention, 61% control) reported that their child qualified for free or reduced-cost lunch as part of the National School Lunch Program (NSLP), with only a few families reporting that they did not qualify (4% intervention, 7% control).[2] In contrast, the majority of families (87% intervention, 74% control) reported not receiving Section 8 housing assistance, with only a few families reporting they did (6% intervention, 17% control).

The sample of 108 children was 48% male and 52% female for the intervention group and 52% male and 48% female for the control group. Children's ages were between 4 and 5 years and was equivalent across both groups, with four-year-old's comprising 68% and five-year-old's comprising 32%. The majority of children (96% in both groups) spoke English as their first language at home and only a few spoke Spanish (4% intervention, 2% control) or Chinese (2% Control). Similarly, across both groups, a vast majority of children (84% intervention; 80% control) were not part of an Individualized Education Program (IEP). Only a few families reported their child received an IEP (9% intervention, 13% control).

Families in the intervention and control groups were also asked how much time their child spends playing with toys or games that helped them learn to code (see Table 1). Chi-square tests showed no differences between the two groups for playing with toys or board games, such as Code-a-pillar and Robot Mouse. However, chi-square tests indicated significant differences between the groups for time spent playing with games on tablets, computers, or cell phones that helped them learn how to code, such as Scratch Jr. and Kodable ($p < .01$).

For additional family background characteristics, see the appendix.

2 A quarter of the intervention group parents and a third of the control group parents did not know if their child qualified for the NSLP.

Table 1. Parents' reports on family coding experiences pre-intervention by condition (N = 108)

Coding Experiences	Intervention *n* = 54	Control *n* = 54
Toys or board games that help your child learn how to code (e.g., Code-a-pillar, Robot Mouse, BeeBot, Robot Turtles)		
No Time	35%	30%
Some Time	37%	56%
A lot of Time	28%	15%
Games on tablets, computers, or cell phones that help your child learn how to code (e.g., Scratch Jr., Kodable, codeSpark Academy, Lightbot)**		
No Time	35%	20%
Some Time	20%	48%
A lot of Time	44%	31%

***p<.001; **p<.01; * p<.05

Data Collection & Analysis

Participating families completed the study within a period of six weeks, between February and May 2019, using either *AHA! Island* videos and hands-on activities or the control materials. Each week, families were encouraged to watch 2–6 videos and do 2–3 hands-on activities, for approximately 50–80 minutes of joint engagement per week. To address the research questions, researchers collected data from the following sources during and around the families' exposure period to the study resources:

- 151 parent pre-surveys (76 intervention, 75 control)
- 108 parent post-surveys (54 intervention, 54 control)
- Learning Task 1 (Sequence Cards) outcomes for 53 children (25 intervention, 28 control)
- Learning Task 2 (Pizza Task) outcomes for 53 children (25 intervention, 28 control)
- Learning Task 3 (Bracelet Task) outcomes for 53 children (25 intervention, 28 control)
- Learning Task 4 (Duplo Task) outcomes for 53 children (25 intervention, 28 control)
- Transfer Task (Robot Mouse) outcomes for 24 children (24 intervention, 0 control)
- Phone interviews with 14 parents (14 intervention, 0 control)

Learning tasks were not aligned to *AHA! Island* content. Instead, tasks were designed to align to the CT learning goals that were identified at the beginning of the project, and they served as the foundation for the development of the videos and hands-on activities. The learning tasks were designed specifically for this study and aimed to assess children's knowledge of algorithmic thinking, the debugging process, and the design process.[3] The transfer task, also specifically designed for this study, aimed to assess children's

3 Details about each learning task and the transfer task are available in the appendix.

transfer of CT skills to a developmentally appropriate pre-coding activity using a programmable toy, the Robot Mouse. This task prioritized the participation of 5-year-olds.[4] Parent surveys included both closed- and open-ended questions regarding basic demographic information, existing constraints, habits, behaviors, attitudes related to hands-on activities in the home, and family media habits. Parent phone interviews were semi-structured and elicited parents' experiences with the learning resources, their descriptions of child behaviors related to implementation, and attitudes related to at-home experiences using the resources. Table 2 displays the data sources used to address each research question.

Table 2. Data sources addressing each research question

Research Questions	Data Sources
RQ1: To what extent are the *AHA! Island* parent-child engagement resources (videos, hands-on activities, parent supports) useable and appealing to parents?	Parent pre/post surveys Parent phone interview
RQ2: What evidence exists that the resources, when used during co-engagement between parent and child, promote CT skills and dispositions, including testing and iterating, tolerating ambiguity, persistence, and curiosity in children?	Parent phone interview
RQ3: What factors work together to support or impede effective use of the parent-child engagement resources?	Parent pre/post surveys Parent phone interview
RQ4: Are preschool children that experienced video and engagement with their parents better able to apply CT Core Ideas (algorithmic thinking, debugging, and design process) relative to children in the control group?	Parent pre/post surveys CT learning tasks
RQ5: Does the use of parent-child engagement resources increase parents' interest and comfort in engaging in hands-on activities in which preschool children apply their CT?	Parent pre/post surveys Parent phone interview
RQ6: Do parents who use parent-child engagement resources report that CT becomes more of a habit of mind in their children's daily lives?	Parent pre/post surveys Parent phone interview
RQ7: Do 5-year-old children that participated in the *AHA! Island* intervention demonstrate enhanced CT knowledge that transfers to a programming environment?	CT transfer task

4 Because the transfer of CT skills to a novel context was expected to be the most difficult for children, we chose to focus efforts on assessing 5-year-old children for whom the cognitive load of learning how to use the toy would not be so great that it would limit their ability to apply any new CT skills.

Analytic Approach

Parent surveys included questions that probed parent perceptions and behaviors related to each outcome pre- and post-intervention, as well as perceptions of the intervention's appeal and utility. Items related to appeal and utility were analyzed descriptively. For outcomes related to parental comfort, confidence with CT, and perceptions of children's CT skills, researchers created factor scores to reduce the data to two different constructs. Using these scores, they then fit two regression models, one for each outcome. In each model, the post-survey outcome score served as the dependent variable, along with the pre-survey score, whether they participated in the *AHA! Island* intervention, and demographic characteristics. These models allowed us to determine if differences in parent outcomes between the start and end of the study were higher for parents who used the *AHA! Island* intervention as compared to the control group. To analyze the interview data, researchers summarized the data thematically and identified cross-cutting themes. The qualitative analysis for the learning tasks focused on understanding and describing children's processes when faced with tasks that afford a CT approach for solving problems or accomplishing goals. Specifically, the results focus on children's typical actions, strategies, and verbalizations, as well as common responses to the prompts and the level of scaffolding children required to engage in each task. Session videos were coded by an independent coder for these processes and actions, and analyses were augmented by notes provided by the assessors. These findings provide information on the differences observed across groups and also important insights for the field about the ways in which children exercise CT skills during problem-solving scenarios.

Findings

RQ1 Utility and Appeal of *AHA! Island* Engagement Resources

Parents found the *AHA! Island* resources easy to use, educational, novel, and engaging.

Families reported strong fidelity of implementation for the *AHA! Island* at-home engagement resources. Eighty-three percent of parents reported watching all or almost all the videos (as compared to 74% of control group families). Ninety-one percent of intervention parents reported that their child watched at least one of the videos more than once, and of this number, 38% reported watching all or almost all the videos more than once, and another 31% reported repeat viewing of around half of the videos. Similarly, families reported strong fidelity of implementation of the hands-on activities with 61% of intervention families reporting that they did all or almost all the study's hands-on activities (compared to 52% of the control group).

Parents commonly reported that they co-viewed videos and did the activities alongside their children. Many of the 14 interview participants (a randomly selected sample of the 76 parents in the intervention group) reported sitting with their child to watch the videos. Some parents emphasized that they explained the concepts from the videos to their children as they watched or during conversations that immediately followed video-viewing.

> *"Oh, he loved it and he of course loved that I'm sitting right next to him, because usually cartoons I'm not sitting next to him for these things. It's kind of like, okay, your time to watch, my time to go maybe have me time or get things ready for the next day... So, him and me sitting together, it was really special for him."*
>
> *- Parent of a 4-year-old*

Across multiple data sources, intervention parents reported that the materials for exploring CT with preschool children were easy to use. Most parents who experienced the *AHA! Island* intervention agreed or strongly agreed that the tablets with videos and hands-on activities were easy to use (93%) and that the hands-on activities were clear (96%). Most of the parents that we interviewed found the instructions for the activities easy to follow. Parents appreciated that the activities included concise instructions on what to do, guiding questions to help them engage with their children during the activities, and ways to extend the learning after the activity was over.

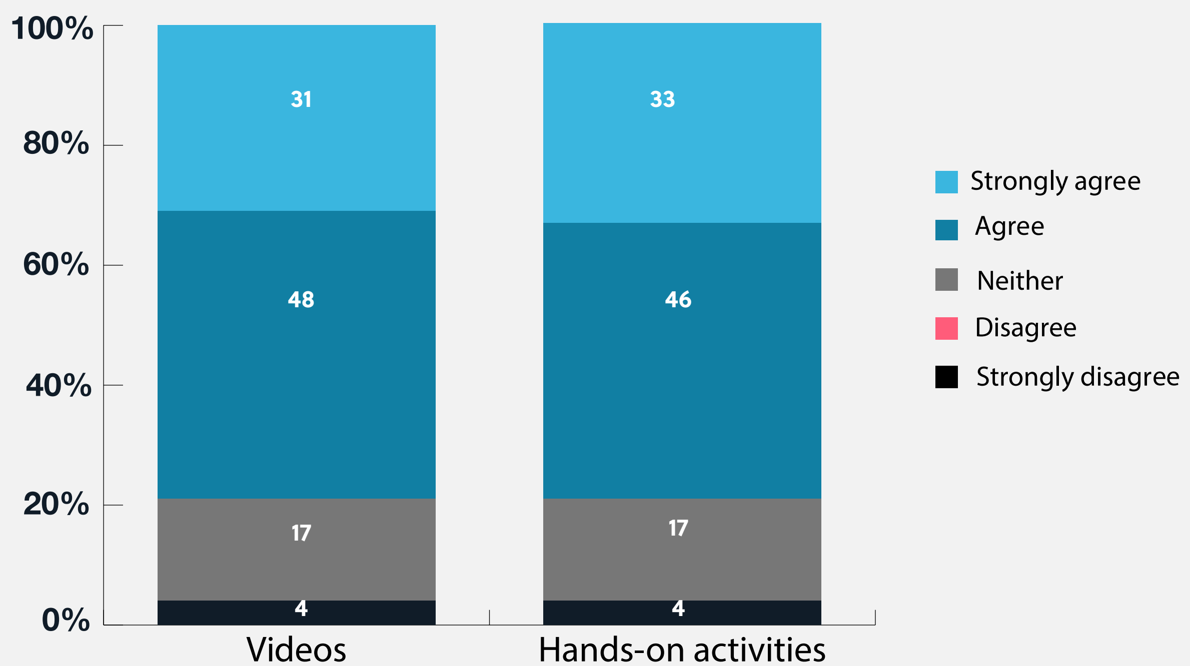
Parents thought that the learning model was appealing. Seventy-nine percent of parents strongly agreed or agreed that both the videos and hands-on activities helped them understand what CT is (see Figure 2). All interviewed parents echoed the sentiments captured by the survey data, stating that they liked many aspects of the CT learning resources. They appreciated that the videos were educational and engaging. Parents also emphasized that they liked the fact that the videos were straightforward and easy to understand and that the content was age appropriate. Parents also liked how the videos taught children to talk about their emotions, such as how to deal with sadness or frustration when something is going wrong.

"We can be really like corny and traditional like when it comes to some of the stuff that's out there compared to what some other kids are allowed to watch. So I thought that this was something that I don't have to worry and just check.... I'm like, oh, he could sit there and watch those over and over all day and I'm perfectly fine with that. I thought that they were just really clean and simple and sane if that makes sense." – Parent of a 5-year-old

Most interviewed participants liked that the activities were educational and engaging. Interviewed parents liked how the activities gave them ideas about how to play with their children and how they encouraged creativity and curiosity in children. Several interviewed parents reported that they used their planned hands-on activity time to create special parent-child moments. Their responses indicated that they looked forward to spending time with their child in this way.

Several parents thought that the *AHA! Island* activities were novel and exciting opportunities to learn and play. One parent said, *"Actually I'd never done like play dough, having him making stuff before."* Another parent reported that her daughter liked being given the chance to use safety scissors because she had never been allowed to cut using regular scissors before. Parents consistently reported that their children liked the chance to make things and be creative with their parents.

Figure 2. Parental reports of learning about CT from the videos and hands-on activities



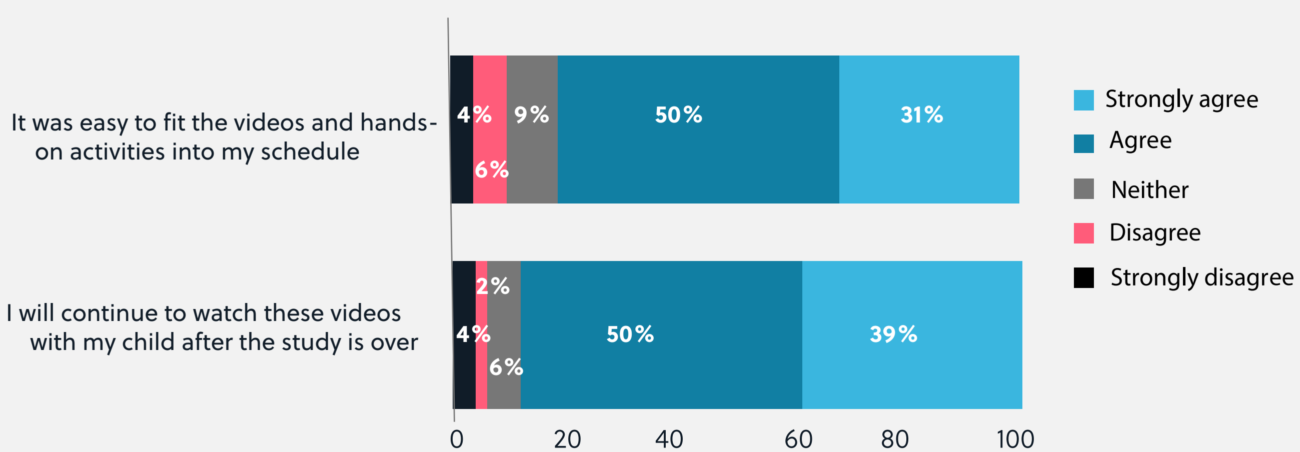
"I liked actually doing stuff with my kid. And the fact that we had something that we had—not that we had to do it, but something that we were doing together. And basically, it teaches me more that I could go out and get different stuff. Because after that I went out, I got like Q-tips and you made like boney ones and little heads and stuff like that. With stuff like that, it teach you how far you can take a kid. You don't just limit them to school, but at home, you can do different stuff with them. Not only reading or writing but hands-on. He's like "I and mommy is doing it. I and mommy are making it." So that was pretty cool, you know." – Parent of a 5-year-old

Parents thought that their children enjoyed the *AHA! Island* learning resources. In post-intervention surveys, most parents agreed or strongly agreed that their children liked the videos (93%) and hands-on activities (96%). Parents thought, that like themselves, their children enjoyed the engaging characters and that the hands-on activities allowed them to try new things. Some parents specifically emphasized how one-on-one experiences with their child are special, noting that their child seemed to enjoy having that dedicated parent engagement time.

Parents reported that the *AHA! Island* intervention was something that worked well within their lives and that they'd be enthusiastic about continuing to use resources like this in the future. Almost all families (82%) agreed or strongly agreed that the CT intervention was easy to fit into their schedules, with less than 10% disagreeing or strongly disagreeing. Similarly, 89% reported they would continue to use the intervention resources beyond the study (see Figure 3).

"That we're all together. We were all together doing them. Most of the time he's playing on his own or he's playing with his sister, but the fact that I was there, it made a big difference." - Parent of a 4-year-old

Figure 3 Intervention parents' report on appropriateness and ease of use of intervention



Note: Bars do not equal 100% due to rounding of percentages.

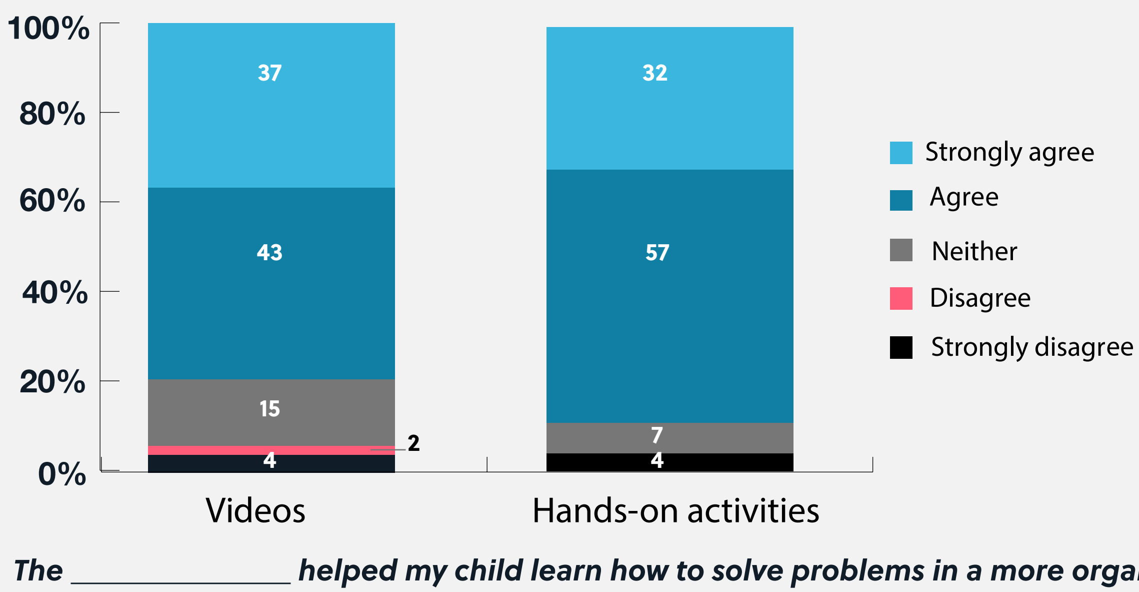
Promoting CT Skills and Dispositions

Parents thought that the *AHA! Island* resources promoted new problem-solving skills and dispositions (like patience, persistence, and teamwork) in their children.

Most parents believed that the *AHA! Island* learning model supported the development of CT-oriented problem-solving skills in their children. The majority of parents either agreed or strongly agreed (80%–90%) that the videos and hands-on activities helped them learn what CT is, helped their child to solve everyday problems, made their child excited about seeing the characters solving problems, and helped their child learn how to solve problems in a more organized way (see Figure 4).

Parents frequently reported that their child learned new problem-solving strategies from the *AHA! Island* learning model. Parents reported that their child learned how to solve problems using CT skills, including breaking down large problems, using trial and error, and applying new dispositions, such as sharing and teamwork. Table 3 shares a select number of parent reflections on child learning, organized by overarching themes.

Figure 4. Intervention parents' report on children's learning from the intervention



Note: Bars do not equal 100% due to rounding of percentages.

Table 3. Sample parent responses when asked about child learning

Themes of Child Learning	Example Parent Reflections
Solving problems by sequencing or debugging a series of steps	» "[My child] used what she learned from the videos to clean and organize her room. She figured out the steps she needed to take in order to organize her room. Then she carried out those steps." » "He could not find his shoes then he said mommy let's think what I did when we came in and follow my steps then he said I wash my hand went in the closets I think that's where it is and for sure that's where he left it." » "He was getting ready to go outside. He was unable to put his jacket on. Then he looked closely and said oh, it's inside out. He then turned the sleeves the right way and was able to put it on. He then looked at me and said, 'I stepped it out.'" » "Yes his toy was missing a piece and he became a little frustrated until I reminded him follow steps on the instruction to fix it and he was super excited when he got it right." » "My son was putting together some train tracks, and they didn't all fit together properly. He said, "Mama, monkey huddle!" He wanted us to put our heads together, then said, "thinking positions!" struck a pose, and asked me to do the same. He thought through the problem in steps, came up with a plan, then worked for a while to fix the tracks. When it didn't work easily, he didn't get overtly frustrated, just said he needs to improve the tracks and came up with a new plan."
Organized thinking	» "Yes, my child cleans up his room more organized big toys with big toys little toys with little. He also sets his table himself before eatingg." » "She then helped me do laundry separating clothes by colors and creating patterns."
Trial and error	» "From making the house for Ellie she learned how trial and error then manage to make the right fit for her teddy she now call Ellie." » "She made a dress from paper for her doll and while putting it on, it tore. She then went ahead to get tape to put the parts torn apart together while leaving more room for her dolls arm."
Dispositions	» "My child talks about the monkeys and wants to make stuff around the house and use his imagination more." » "It made her think and patience [sic] to find the solution in a problem." » "Yes, sharing with his sister and wanted to teach her the lesson he just learned."

Parents who participated in interviews further illustrated how the intervention supported new CT skills and dispositions in their children. Parents talked about their children following directions and even repeating some of the language around "checking their steps," which was presented in the *AHA! Island* media. Parents also described their children as being more independent and autonomous following their exposure to *AHA! Island* videos and hands-on activities. Parents noted that they saw their children communicating and interacting with them and with others more effectively. Parents reported that they also observed their children persevering and having patience when they tried to accomplish different things.

> *Because even when sometimes, if he's doing something and it doesn't work, he would just leave it alone. But then after that now, then he was like, "Oh, mommy, but the monkey said you should think, trace your steps, go back. If it doesn't work, you do it again and add something else. I'm going to do this and see how it works." And he did. . . . Every time he's doing something, and it doesn't work, he says, "But Mommy, the monkey says . . ."*
> *- Parent of a 5-year-old*

> *"He really used them (CT skills), and he uses them a few times a week at least, not just when we're doing the activity after the video but just at other random times. I think he has even said 'Let's step it out,' like some of the language and certainly the concept of like stepping back in thinking about what you need to do and coming up with a plan. That was not something I really saw him doing before." – Parent of a 4-year-old*

Several parents thought that the *AHA! Island* intervention resources would help their children be ready for school. For example, one mother noted that she thought the resources helped her child to develop a work ethic. She said: *"My son learned how to like to do some stuff . . . like he learned how to be independent. Then he learned how to follow some directions by himself."*

RQ3 Factors That Support or Impede Effective Use of *AHA! Island* Resources

Parents praised *AHA! Island* resources for their effectiveness in fostering joint engagement, including: the clarity, simplicity, and appeal of the resources; the ability to integrate them into everyday routines; and the inclusion of support for parents. The biggest impediment to at-home use was the difficulty in finding time for family activities.

Most parents indicated strong support for the *AHA! Island* resources, particularly because of their appeal, ease of use, and the ability to fit videos and hands-on activities into everyday routines. Most intervention parents (81%–86%) agreed or strongly agreed that their child enjoyed the videos and hands-on activities, which made children excited to participate.

> *"And so, he really liked—he really took to the characters and it also obviously really entered his imagination . . . and sometimes he would even be playing with like Legos or he was making a fort and he wanted me to call him Fred. So, the characters just kind of entered into his plan in other ways too." – Parent of a 4-year-old*

Parents indicated that the parent-focused instructions for watching videos and doing hands-on activities provided to families were effective in fostering their participation in the study. Ninety-two percent agreed or strongly agreed that the tablet was easy to use for media viewing, and 97% indicated that the directions for how to do the hands-on activities were clear. The simplicity and clarity in how to use these materials supported parental involvement in using the materials at home.

Commonly, videos and hands-on activities were praised for their brevity and simplicity. Several parents mentioned how it was easy to fit in the short videos during certain times of their daily routine, including after school, after dinner, or while older siblings were still at school. One parent noted: *"We kind of found a time that worked for us. He gets home from preschool and I get home from work pretty late. And so, we just found a time that we would just do it before dinner. And my son actually looked forward to it. It was like a nice one-on-one time. We have pretty busy lives. So yeah, we just kind of worked it into the routine and it really quickly became something he looked forward to it."*

While many parents appreciated the simplicity and straightforwardness of the videos, a small number of parents had constructive criticism for the video formats. Two of the interviewed parents thought that the videos were too short. Another small number of parents thought that the videos were a bit repetitive, with the same characters appearing across videos. They thought that this may have contributed to their child being uninterested at times. Some parents thought that the pacing of some of the videos felt rather slow but acknowledged that this was likely an appropriate pace for preschool children. And finally, one interviewed participant thought that the animated story videos could have been wrapped up with better conclusions.

The main barrier to implementation was the occasional lack of available parent-child time for co-viewing and hands-on activities. Some said that it was challenging to find regular time for a set of planned activities, whereas others talked about how the busyness of life created occasional difficulties that made this type of planned learning harder to do.

Some of the parents who felt that it was difficult to find time within their family's routine attributed this challenge to having multiple children. One mother reported, *"The only challenge that I really did have was the timing."* When asked what the specific challenge was, she said, *"Well, I have another son. So, I usually do the homework with him first and then me and my son will sit down and do a video. But I guess it was one of* *those weeks that I was so busy, and I really didn't have time to actually sit down to do that extra video with him, but we did catch up the next week and we did."* Despite this, she noted, *"Because we usually don't do things like that at home together . . . that was a new experience for both of us which was fun."* Another mother of five, who implemented the resources with her son said, *"You know, sometimes, because I'm expecting a baby next month, sometimes it's hard for me to go on it with him, that's why I tell the sister to go over to it with him."* When we asked how we could make it easier, she suggested being able to include all her children in the activities would allow her to better integrate the resources into her family's routine. She said, *"Make it like a family thing."*

However, most families who did find it easy to integrate the resources found various ways to do so, even when they were limited by time. Several parents emphasized the importance of finding time to do this within their daily schedule, discussing how it was easier to commit to planned time rather than other kinds of spontaneous learning activities. Others discussed prioritizing this type of work on weekends where their schedule was a bit more flexible. One participant for this study was the child's grandfather. During the interview, he stated, *"It was great because you know, I'm retired now, so I have time to spend with her and go through those videos. So, I spend a lot of time with her."* He added that his granddaughter's father implemented the hands-on activities with her on weekends.

Some families found it challenging to gather materials for the activities. While some parents felt that everything they needed was already at home, three interviewed parents noted that gathering the supplies was challenging. Still, most of the parents who did report challenges gathering materials, reported finding it easy to fit the *AHA! Island* resources into their routines. For example, one participant said, *"I would say sometimes the activities took a little while to gather materials to kind of set up. I guess a couple of the later ones, it took a little bit longer and that was just a bit trickier because we have a kind of tight turnaround time in our household at night and that was the only time when it really fit in. But it still worked out okay. We found ways to do it and I think there was maybe one or two activities where we started to set it up and realized it was totally going to work like before dinner and then bedtime routine, and so we would just continue with it the next night."*

Some parents noted that language was a challenge for them during the study. A couple of parents whose first language was not English reported having difficulties using the instructions for the activities. When we asked a Spanish-speaking mom whether she would say that the instructions were easy or difficult to understand, she responded, *"Yes, it was kind of difficult. . . . It's not as specific as I want it to be."* To resolve this issue, she pointed out that she had her daughter help her to engage her son in the activities. A similar strategy was used by a parent who spoke French at home. She also asked her older daughter to do the activities with her son. Additionally, language became a challenge when children did not understand a certain concept presented in the video. One parent who spoke Chinese at home pointed out that when her son did not get a certain concept, she would tell him to watch the video, rather than explain it differently. A Spanish-speaking mother suggested that the videos have prompts that could provide a clue to the solutions of any particular problem that was presented.

A little more than half of families, when prompted, agreed or strongly agreed that they would have liked extra help with how to do the hands-on activities with their child. These responses suggest that, while the activities themselves are clear, parents may desire additional coaching on how to increase their effectiveness in supporting these types of joint engagement learning experiences with their children.

RQ4 The Effect of *AHA! Island* Resources on Preschool Children's CT Core Ideas

While parent perceptions of children's CT learning were similar among intervention and control groups, children that used *AHA! Island* resources with their parents demonstrated some interesting differences in their approach to sequencing-focused learning tasks. Learning task results also shed light onto some of the naturally-occurring CT abilities of young children.

Pre-/Post-Survey Items

As the first step in investigating the potential effect of *AHA! Island* learning resources on parents' perceptions of their children's CT core concepts, the research team analyzed parents' pre-/post-survey items that pertained to parents' reflections on their children's abilities. Prior to and immediately following the intervention, parents were asked to rate their level of agreement with the following five items:

- My child knows how to solve a problem by thinking about the steps needed and then doing them in order.
- When something is not working the way my child wants, he/she can figure out if there's a problem and come up with a way to make it work.
- When my child wants to make something new, he/she knows how to create it, then test it to see how well it works, and then use what he/she learned to improve it.
- When my child has a problem, he/she can think creatively about how to solve it.
- When my child has a problem, he/she can keep trying until the problem is solved.

The research team examined the reliability of this five-item scale (Alpha = .87 and .88 pre- and post-survey respectively) and created individual factor scores to use as an outcome measure. Using multiple regression analysis with this CT ability factor score as the outcome, researchers included a pre-survey factor score as a baseline measure along with important control variables.[5] Multiple regression analyses were conducted with the construct as the outcome.

When controlling for pre-survey results, there was not a significant main effect of condition on the construct of parents' perception of children's CT skills nor was there a significant interaction effect between pre-survey and condition on the outcome. However, it should be noted that pre-scores were high, limiting the amount of room that was available for improvement. Regression coefficients for this final model and item-level descriptive statistics are in the appendix.

CT Learning Tasks

To more directly assess the potential effect of the *AHA! Island* learning resources on children's CT Core Ideas, the research team devised a series of CT learning tasks. These tasks were hands-on opportunities for children to use CT skills to solve problems or accomplish task goals. Following, we provide a brief overview of the learning tasks. (See the appendix for detailed task descriptions.)

Sequence Cards Summary. This task explored children's ability to sequence, which is a subtopic of algorithmic thinking. Children selected and arranged a set of nine cards to create a sequential order for brushing teeth. After the cards were in order, the child was asked to verbally describe the sequence.

5 The analysis dropped 10 parents due to incomplete control variable data. Variables with relationships p >.10 were removed in producing final model estimates, including child gender, mother education, father education, race, educational media viewing, and time with coding games.

Pizza Task Summary. Children engaged in a hands-on sequencing task by making a pizza with felt ingredients and describing the role of the crust in the sequence of making a pizza.

Bracelet Task Summary. Children engaged in a structured opportunity to utilize debugging strategies by making identical bracelets.

Duplo Task Summary. Children's design process abilities were assessed by presenting children with a set of Duplo® building blocks to create a house for a character that either keeps the character dry or is large enough for many characters.

Differences between Intervention and Control Groups

To evaluate the potential influence of the *AHA! Island* intervention on children's use of CT core concepts, researchers descriptively and qualitatively compared the performance of children in the intervention group to the performance of children in the control group. While children's performance with the tasks were similar across groups in many ways, the research team found the following interesting differences.

Children in the intervention group appeared to try different strategies for attempting to sequence the cards and while defining the steps in the pizza task. With the card sequencing tasks, the intervention group more frequently looked at their proposed solution and took steps to improve it. For example, children in the intervention group would often select cards, start placing them in a sequence, but then make changes as they did this, either by changing the cards they selected or moving the cards around in a different order. Similarly, the intervention children changed their strategy as they engaged in the pizza sequencing task by selecting additional ingredients or removing ingredients as they prepared their pizza.

Compared to the control group, children in the intervention group were able generate a greater number of potential steps when engaging in the pizza making task. With the pizza sequencing task, children in the intervention group not only included steps that were commonly used across both groups, such as including the crust, sauce, and toppings, but they also included more detailed steps related to cooking the pizza, such placing the pizza in the oven, closing the oven door, adjusting the dial to set the temperature, waiting a few moments to pretend the pizza was cooking, and removing the pizza with a tray.

Compared to the control group, children in the intervention group appeared to prioritize the importance of the crust being an early step to pizza making. This indicates that they may have a stronger grasp on the importance of order.

In the debugging and design process tasks, there were few overt differences between the intervention and control groups; however, results indicate that the control group children needed fewer scaffolds than the intervention children to complete the tasks. While these differences appear not to be in favor of the intervention group, they are important in describing the range of preschool children's behavior as they engage in CT-related activities. When evaluating the bracelet and Duplo tasks debugging results, the control group differed from the intervention group in that they needed fewer scaffolds and showed slightly more engagement across the task. For example, children in the control group needed fewer prompts, such as *"How do you think we could make sure the beads on my bracelet will be the same as the beads on your bracelet?"* or scaffolds such as *"Check the beads next to each other and see if that helps."* When evaluating the Duplo task design process results, the control group created their own solutions more frequently without scaffolding as compared to the intervention group. For example, children in the control group needed fewer prompts, such as *"Is there anything on the table that you could use to help solve his problem and keep him dry?" or scaffolds such as "Can you help Hugo stay dry by adding to these blocks."*

Baseline Abilities of Preschool Children

The CT learning tasks provided new insights as to the expected abilities for preschoolers to engage with CT core concepts. The following represent lessons learned across the full sample (regardless of condition) when children's use of CT strategies are considered.

Preschoolers in both groups were able to engage in simple sequencing activities to solve a problem or complete a design challenge. The preschoolers in our study were able to select cards showing steps in a process, describe what is happening on those cards, and organize the cards in a logical or semi-logical way. Likewise, preschoolers were able to select relevant materials and arrange them in logical or semi-logical ways to create a play pizza.

Preschoolers often required scaffolds from an adult in order to engage in CT tasks that had multiple parts. These scaffolds helped prompt children about the types of activities or behaviors required for the next step in problem-solving. For example, in the Duplo task, scaffolds that helped to guide the child's actions were used to remind children of the task goals, such as, *"I think that there are too many people, and they won't fit inside this house."* Whereas other prompts provided more specific feedback to influence children's ability to engage with the problem: *"I wonder if we could fit all of his friends if we made his house bigger using these blocks."*

Preschoolers were able to engage in simple debugging activities, creating sets of identical patterns using objects and correcting inconsistencies by comparing two sets of objects (i.e., one-to-one correspondence). For example, during the bracelet task, children frequently checked the beads using a direct comparison strategy, considering bead color, bead pattern, and the number of beads in the sequence. In order to conduct this direct comparison, children laid beads next to each other or put beads on the strings simultaneously. This skill seems to be developmentally appropriate with the use of hands-on materials and supportive instructional practices.

Preschoolers were able to engage in the design process to create and test solutions, using materials to create solutions and test those solutions to improve on their design. For example, preschoolers were able to leverage their prior knowledge and experience (i.e., knowing that the character needed something to block the rain) and use their imagination to build upon existing structures or take apart and remake a section of the building to serve a design need.

RQ5 The Effect of *AHA! Island* Engagement Resources on Parent Interest and Comfort Supporting Child CT

While survey data did not yield significantly different results in comfort and confidence among intervention and control parents, data gathered from interviews with intervention parents showed evidence of growth in their understanding of CT and reported new strategies for supporting CT with their children. Parents' comfort and confidence with supporting their children's CT abilities were explored through multiple sources of data. We explore our findings from pre-/post-surveys, the analysis of parents' CT definitions, and parent interviews below.

Pre-/Post-Surveys

To investigate the potential effect of *AHA! Island* learning resources on parent comfort and confidence, the research team analyzed parents' pre-/post-survey items. In this set of items, the survey asked parents to reflect on their own confidence in supporting their child's CT learning. Prior to and immediately following the intervention, parents were asked to rate their level of agreement with the following four items:

- I know how to teach my child computer science skills by helping him/her solve everyday problems.
- I want to help my child learn skills that he/she needs for learning how to code later in life.
- I am confident that I can help my child learn how to solve problems.
- I am confident that I can help my child learn skills that will prepare him/her to learn how to code when he/she is older.

The research team examined the reliability of this four-item scale (Alpha = .68 and .86 pre- and post-survey respectively) and created individual factor scores to use as an outcome measure. Using multiple regression analysis with this CT confidence factor score as the outcome, researchers included a pre-survey factor score as a baseline measure along with important control variables.[6] Multiple regression analyses were conducted with the construct as the outcome.

Controlling for pre-survey results, there was not a significant main effect of condition on the construct of parents' confidence in supporting children's CT skills. However, there was a significant interaction effect of pre-survey by condition, meaning that the relationship between the pre- and post-survey responses was moderated by condition; descriptive analyses show a general trend of lower post-survey ratings on some items related to confidence. These results suggest that parents may have re-calibrated their understanding of CT over the course of the study. This may have led to lower post scores related to confidence. Regression coefficients for this final model and item-level descriptive statistics are located in the appendix.

Analysis of CT Definitions

Because the project team understood the limitations of this kind of pre-/post-analysis, particularly parents' likelihood of over-reporting comfort and confidence, we analyzed the pre-/post-survey open-response question, *"What do you think 'computational thinking' means?"* The goal of this analysis was to further investigate parents' understanding of CT prior to and after the six-week intervention. Of the full study sample, 102 parents provided responses that were

6 The analysis dropped 10 parents due to incomplete control variable data. Variables with relationships p >.10 were removed in producing final model estimates, including child age, child gender, father education, educational media viewing, and time with coding games were removed.

included in this analysis. For this, we developed a coding scheme to help describe the presence or absence of certain features when defining CT and to draw comparisons between the *AHA! Island* intervention and the control group. Parents' responses were coded by assigning a binary code (0 = no; 1 = yes) for each of the following characteristics:

- Inclusion of CT Core Idea terms
- Use of CT Catchphrase language
- New CT-related dispositions
- Reference to CT as important for learning "specific academic subject"
- Inclusion of computing-related references
- Absence of CT-related definition

We further coded for sub-characteristics for each of the six features, which is provided in more detail below. The research team analyzed 102 out of 108 responses.[7]

Prior to beginning the study, parents across both groups did not indicate a strong understanding of CT. When providing their pre-study definitions, parents mostly included computing-related references (43% intervention, 36% control) or dispositions (43% intervention, 28% control). Few parents included references to a CT Core Idea (4% intervention, 2% control), used CT Catchphrase language (6% intervention, 4% control), or referenced CT as important for learning a specific subject (2% intervention, 0% control). Tests for baseline equivalence revealed no differences ($p > .05$) between the intervention and control groups for these features.

Analysis suggests that some shifts occurred in *AHA! Island* parent definitions of CT. Three main shifts that our analysis revealed are as follows.

1 Inclusion of CT Core Idea Terms

Although not explicitly referenced in the videos and hands-on activities provided to intervention parents, the intervention's primary focus was on the CT Core Ideas of debugging, sequencing (a subtopic of algorithmic thinking), and the design process. Therefore, parents' definitions were coded for inclusion or indication of these three CT Core Idea terms. Following, we highlight some of the most prominent descriptive differences between definitions given by the intervention group parents and those given by the control group parents.

Prior to the study, few parents (4% intervention, 2% control) included a CT Core Idea term in their definitions. After completing the study, a few more parents in the intervention group (12%) included a CT Core Idea in their definitions whereas the control group remained the same (2%). Almost all parents who showed indication of a CT Core Idea included some reference to sequencing. Only one intervention parent showed indication of the design process. Following are a few examples of the differences between control and intervention group CT definitions pre-intervention versus post intervention (see Table 4). The control group parent definition example is shared to show an example of what a parent had prior to and following the study without CT learning support.

7 Approximately 6% (6 parents) of the study sample did not respond to this question, therefore they were eliminated from the analysis. However, the 10% (11 parents) of parents that responded "I don't know" either at pre- or post-intervention were kept in the sample.

Table 4. Sample pre-post comparisons between CT definitions of intervention parents and control group parents

	Parents' Pre-CT Definition	Parents' Post-CT Definition
Control Parent 1	"*Understand the meaning of sequential actions*, task etc."	"*Able to understand sequence* to understand." (Sequencing)
Intervention Parent 1	"To *think like a computer*."	"*Using steps in order to solve a problem*." (Sequencing)
Intervention Parent 2	"The ability to *solve problems by using a computer*."	"Computational thinking is *solving problems in a more organized and creative way by handling problems step by step*." (Sequencing)
Intervention Parent 3	"I believe it means *thinking like a computer*. Having the ability to put understand situations and thoughts together fast. This I believe may or may not be affected by a child's *exposure to computers*."	"Computational thinking is helping children *process ideas or solve everyday problems* in a step by step method in order to get expected or good results, somewhat *like the real computers do*. This *helps them with learning to code "coding"*." (Sequencing)
Intervention Parent 4	"I think of *math-related concepts*. I think of addition, subtraction, etc. I also think of being able to hold the idea of an amount in one's mind, and *having an abstract concept of a number that can be added to or subtracted from in the mind*."	I think of *planning and working through problems in an organized way; naming a problem, planning an approach, testing it out and improving it; keeping track of objects and applied addition/subtraction; breaking things down into parts in order to think them through*. (Design Process; Systematic Thinking)

As previously mentioned, chi-square tests of independence showed a difference ($p < .05$) between the intervention and control groups, which indicates that there was a relationship between condition and parents' inclusion of a CT Core Idea term in their definitions after the study.

2 Use of CT Catchphrase Language

Embedded throughout the videos and hands-on activities were CT Catchphrases related to the CT core skills of debugging, sequencing, and the design process. References to language such as "check your steps" and "make it work" (debugging); "step it out" (sequencing); "create, test, and improve" (design process); and similar language were coded when analyzing parents pre- and post CT definitions.

Very few parents across both groups showed indication of use of CT Catchphrase language prior to the study (6% intervention, 4% control); however, after the study, intervention parents showed more indication of use of CT language compared to control group parents (8% intervention, 0% control), although small in number. As previously discussed, chi-square tests of independence showed no difference ($p > .05$) between the intervention and control groups at pre-intervention, but they did at post-intervention ($p < .05$). This difference indicates that the *AHA! Island* intervention may have influenced parents' use of CT Catchphrase language. In Table 5, we provide pre-/post-intervention definitions of these intervention parents, which pre-intervention definitions show no indication of CT Catchphrase language.

Table 5. Sample pre- and post-comparisons between CT definitions of intervention parents that used CT Catchphrase language

	Parents' Pre-CT Definition	Parents' Post-CT Definition
Intervention Parent 5	*"Problem-solving* materials *on computer."*	"Understanding the task and the *(ability) to think it through for solutions*." (Similar to step it out)
Intervention Parent 6	*"Using computer to think to calculate and learn."*	"*Step it out. Steps* that can help you *problem solve*." (Step it out)
Intervention Parent 7	*"Learning from the computer."*	"Watch, *create and improve*." (Create, test, improve)

3 Inclusion of Computing-Related References

The CT definition that was provided in the parent overviews in the *AHA! Island* activity packets included computer-related references, particularly "coding" and "computer programming." Therefore, parents' CT definitions were coded for these and other computer-related references such as "computers," "computer science," and "technology."

The *AHA! Island* intervention may have helped intervention parents expand their conception of CT. Prior to the study, parents across both groups mostly referenced "computers" as part of their CT definitions, particularly "thinking like a computer." Computer-related references were less frequently reported at post-intervention (20% intervention, 30% control) compared to pre-intervention (43% intervention, 36% control) for both groups, but especially for the intervention group. In other words, the intervention group parents changed their conception of CT in a way that was not seen in the control group. Table 6 includes a few examples from both groups that indicate the variability in the complexity of the definitions, with the first examples only referencing "computers" and the second showing an indication of CT Core Ideas and dispositions of "way of thinking" or "problem-solving."

Table 6. Sample pre- and post-comparisons between CT definitions of intervention group parents and control group parents to note changes in computing-related terminology

	Parents' Pre-CT Definition	Parents' Post-CT Definition
Control Parent 7	*"Things to do with computers."*	"To be able to comprehend what your reading."
Control Parent 8	"I am guessing that it refers to *the way you think to figure things out*. But it could also be related specifically to *how computers process information, or think*."	"I'm still just guessing. I think it means the *way we process information and connect information*."
Intervention Parent 11	*"To use computer."*	*"To think and solve problems."*
Intervention Parent 12	*"Problem-solving with technology."*	*"Working together using technology."*

Parent Interviews

A subsample of parents from the intervention group were selected to participate in an interview to gather additional details about their at-home joint engagement experiences.

Post-intervention, many parents reported that they learned new strategies for teaching their children about problem-solving. During interviews, some parents reported being inspired to think creatively about the kinds of activities that they can do with their children to engender learning. Others realized new ways of explaining concepts to support their children's learning.

"I learned how to be more patient with him also when it comes to teaching him things and not try to rush him into doing something that he's not ready for, but if he didn't know how to do it, I would, you know, we could take a break and get back to it later or another day if he wasn't getting it." – Parent of a 4-year-old

"It's just that I didn't think to myself, like teaching him how to set the table. I didn't think to sit down, all right, I'm going to teach my son how to set the table but when the activity was there, I'm just like, wow. Why can't—I thought about this before?" – Parent of a 4-year-old

"I had to be patient and to not give up. And if there's a bump in the road when he's trying to do something and he finds it difficult, it helped teach him to stop and think of the steps necessary and which is a simpler way to do it." – Parent of a 4-year-old

RQ6 The Effect of *AHA! Island* Engagement Resources on Children's Use of CT in Everyday Life

Parents observed changes in how their children approached solving everyday problems and many reported that they would like to continue this type of learning as a family.

In addition to supporting children's development around CT Core Ideas and dispositions, the videos and hands-on activities were also designed to support children's engagement with complex problems in creative and systematic ways. During interviews, we asked parents in the intervention group about the extent to which they saw their children integrating these CT skills as a habit of mind during everyday activities.

Most of the parents interviewed reported that CT became something that their children used in everyday problem-solving. In addition to showing familiarity with Core Ideas that comprise CT, parents thought that the intervention included opportunities for children to further develop new routines, many of which show a propensity for taking a computational approach in problem-solving. Following, we provide some example quotes describing how certain types of behaviors were present as parents explored problems and activities.

> *"I would be able to explain to him about Step it Out and stuff like that. I would even say to him, like, oh, how did you do this, you know, ask the questions that you guys obviously had in the packet or sometimes even just my own and I would always be so happy and call, when he would say, I want to watch Step it Out or Check My Steps and I'm like, oh, yes, it's working." – Parent of a 5-year-old*

> *"At first, he was like, "Mommy, why are they doing that or why are they doing that?" But then I would explain, just let's keep watching it and then you will see how things are. And then after that, we actually did it—we did it the same way. We did it the wrong way, and then we went back and did it the right way again because I wanted him to know the same steps that those monkeys took, that he could go back and do the same thing and correct it. So, if like something happens in his day-to-day life and it does not work out the first time, then he could think about it. What did he not do right, and then how to correct it? Like implementing different steps until he gets to exactly where he needs to be at." – Parent of a 5-year-old*

Parents thought that the *AHA! Island* intervention would be a worthwhile way to continue exploring together. Most parents interviewed were interested in being provided more videos and hands-on activities similar to what they experienced during the intervention to continue their at-home learning. A few parents particularly expressed interest in more of the intervention's game-like activities, citing that these are fun and help children learn new skills and dispositions.

RQ7 Transfer of CT Knowledge to a Programming Environment

During a pre-coding task, children that experienced at-home learning with *AHA! Island* resources were most frequently observed to use their sequencing skills as part of the task; children's application of design process and debugging skills were less frequently observed.

This research question was intended to evaluate the extent to which children who experienced *AHA! Island* resources would transfer the CT strategies to a pre-coding task. To accomplish this, the project team developed an exploratory transfer task using an existing coding toy called Robot Mouse. In the transfer task, children had to code a programmable mouse using a set of tangible arrow cards. Using a set of buttons on the robot's back, children would enter their program so that the robot would move on a green track. Children completed (1) two training trials, (2) two target trials where the child had to get the mouse to a pre-determined location (a piece of cheese), and (3) an open-ended trial where the child could create their own problem to solve. For more details about the task, see the appendix.

Twenty-four children from the intervention group participated in this exploratory transfer task. Because the project team was unsure about the extent to which CT skills would transfer, we decided to focus our attention on conducting a descriptive, qualitative analysis of what children with the intervention could do versus making comparisons to the control group.

For task completion, 100% of the children completed target trial 1; 44% of the children completed target trial 2 (with another 35% partially completing the trial); and 30% of the children completed the open-ended task (with another 17% partially completing the trial). Partial completion included when children completed the task by programming the mouse successfully to get it to its destination, but they did not make a plan using the cards. If the child was either unable to use the cards to make a plan or unable to get the mouse to the cheese on any task, the researcher ended the session and recorded this as the child's last engagement with the task. Below, we present the main takeaways from the children's participation in the task.

Children appeared to understand the 1-to-1 correspondence of the arrow cards to the mouse's buttons. This was particularly true for target trial 1, which had children programming the mouse to move in a straight line. Most children were able to do this with ease, but a few children struggled to see that one arrow card represented the movement of one green square on the track

Children were able to use the Robot Mouse to clearly demonstrate their CT skills; on average, they seemed to be most proficient with sequencing and algorithms and least proficient with the design process and debugging. Researchers scored children's performance on the task with an augmented rubric inspired by Relkin's Interactive Play Rating System (2018). In this rubric, researchers assigned a score to children in each of three domains: sequencing and algorithms, debugging, and design process abilities. Each of the domain scores ranged from 1 to 4 (with 4 being the most advanced) and were summed to create a composite CT score. Researchers also rated students on their overall programming ability. For this sample, children appeared to perform the highest on sequencing and algorithms. Most children were classified as level 3 (44%) or level 2 (48%) on the sequencing and algorithms scale. Only 9% of children were scored as level 1. On design progress, a smaller percentage (26%) of children were ranked as level 3, but 61% of children were level 2 (and 13% level 1). Children were rated least proficient overall with debugging, with 22% at level 3, 57% at level 2, and 17% at level 1. Interestingly, however, one child (4%) was classified at level 4 on debugging. Table 7 lists the results.

Table 7. Transfer task results based upon rubric

Task	Level 1	Level 2	Level 3	Level 4
Sequencing and algorithms	9%	48%	44%	
Design	13%	61%	26%	
Debugging	17%	57%	22%	4% (1 child)

Children experienced challenges relaying their plan to the mouse via its buttons. When the task was easy, children seemed to comprehend how to use the arrow cards to create a plan for the movement of the mouse and then enter the steps using the arrow buttons on the mouse. However, as the task got more challenging, children appeared to struggle with using the arrow cards as a planning step prior to programming the mouse. For example, 74% of children used the cards to make their plan in trial 1, whereas only 35% used the cards fully in trial 2, with another 44% exhibiting partial use. This may signal that, as the task increased in complexity, the use of cards for planning purposes may have become too much of a cognitive load for children to switch back-and-forth between the cards and the use of the buttons.

Not surprisingly, children were able to debug their solutions most easily on the simplest trial but had more challenges when the task became more complex. When children ran into problems with their solution (about 2/3 of children across trials), children's ability to debug their solution was highest on the simplest trial and decreased with task complexity.

Across the trials, a few children were observed to use CT Catchphrases that were modeled in the media. Three children were observed using either "step it out;" "create, test, improve;" or "check your steps" during their task session. These are strong indicators that children are seeing this task as an opportunity to use their problem-solving skills.

Overall, children appeared to emerge as Early Programmers. Researchers ranked children's performance on an Overall Programming Ability scale, with three categories. The majority of children fell into the Early Programmer category (level 2 – 52%), followed by Programmer (level 3 – 39%), and then Proto-Programmer (level 1 – 9%).

Discussion

Our central conjecture was that resources designed for joint parent-child engagement in CT can impact children's early learning of CT skills. Major findings around this conjecture follow.

Findings

Positive Reception by Parents and Children. AHA! Island videos and hands-on activities appeared to have an overall positive reception by both parents and their children. Parents seemed to like many aspects of the videos and hands-on activities. The vast majority of parents thought that both videos and hands-on activities were educational and engaging. Children tended to enjoy the videos as well as the opportunity to learn with their parents and have novel experiences. These findings build on our formative work to suggest that the premise of the intervention is popular with parents and children (Lavigne & Cuellar 2016, 2019).

New Ideas and Behaviors. Overall, parents reported that the videos and hands-on activities gave them ideas about how to engage with their children and how to support their CT learning. Many parents reported that they learned about new problem-solving strategies they could practice with their children during everyday activities. Parents talked about their children following directions and checking their steps, being more independent and autonomous, communicating and interacting with others more effectively, being perseverant and having patience, and overall, problem-solving differently after the intervention. Parents thought that the intervention content helped their children solve problems in more organized ways and become more excited about the challenge of solving problems. Parents also thought that their children brought new dispositions to their approach to solving problems, including independence, persistence, and organization.

Desire to Continue. A large majority of parents reported that their children appeared to enjoy the videos and hands-on activities, with many parents stating that they would continue with these activities after the study was over. These findings are supported by those that we found in the earlier formative stages of research on this project (Lavigne & Cuellar, 2016, 2019).

Increase in Parents' Understanding of CT. Parents also appeared to develop a deeper understanding of computational thinking, as evidenced by the specificity and contents of their CT definitions. Although, many parents did not know the definition of CT at the beginning of the study, after participating in the intervention, many of them were able to identify CT-related competencies when defining CT. This suggests that parents began to become familiar with the skills, attitudes, and behaviors that comprise CT. Thus, parents seemed to gain confidence and competency in what CT is and how it can be used for problem-solving.

Decrease in Parents' Confidence. While there was clear evidence of growth in how the intervention parents defined CT and articulated their understanding of how CT helps children solve problems, the pre-/post-survey items that measured parental confidence did not show significant positive changes. Actually, there was a reduction in the parents' confidence when compared to their pre-survey scores. However, this is unsurprising given that their pre-survey scores were relatively high. It can be posited that, after learning about CT, many parents calibrated their confidence after having a better understanding of what it looks like to support their child's learning.

Children's Performance. There were some interesting differences in the way children performed on the learning tasks. Specifically, we found that children from the intervention group appeared better able to shift their thinking when solving sequencing-related problems in the card and pizza tasks. This evidence is promising, as in the long term, the intervention could support children to think more flexibly and creatively about solving problems using their CT skills.

Parental Challenges. . In previous pilot phases, we asked parents to describe the challenges they faced when engaging in the videos and hands-on joint engagement experiences at home. The most common challenge parents reported was a lack of dedicated time to set aside for these types of activities. This finding was confirmed in the current study. During interviews, some parents discussed how they don't have the time to do these kinds of activities or that they do not always have the materials the activities require. Despite these challenges, parents thought that the *AHA! Island* resources provided new opportunities for engaging in CT learning at home. They also thought that they could continue doing these kinds of activities even after the study was over and that the videos and hands-on activities surfaced valuable problem-solving and social-emotional skills in their children. However, despite this positivity, parents were still very cognizant that time is a critical factor in getting these activities into their schedule. Future research should continue to explore how to integrate this non-coding approach to CT into everyday learning opportunities.

Summation. Our research has yielded new understanding of how young children's practice with the Core Ideas of CT can be nurtured through joint media engagement between parents and children. Through our observations of children's performance on the learning tasks, we have a better baseline understanding of children's CT abilities, particularly when engaged in activities with an adult. Our formative research suggested that adult scaffolding and prompting are important in helping children make sense of sequential processes. The deepest experiences that we observed during joint engagement activities often involved a parent who prompted the child to think about the problem, helped them brainstorm possible solutions or actions, and supported their implementation of problem-solving strategies (Lavigne & Cuellar, 2016, 2019). This was further evidenced in the current research by the number of children who were successful in achieving the CT learning task goals with the support of assessor prompting and scaffolds. We found adult support, such as the use of open-ended questions or prompts for what to do next, to be important in helping children identify problems and to encourage preschool children to think about problems in different ways. The guidance and support from adults may be a critical component in helping children slow down the pace of their exploration, provide the guard rails for children to engage in productive struggles, and to support the use of strategies that help children explore problems in ways that may not be accessible without joint engagement.

Limitations and Challenges

This study has three limitations. First, while our design used a random assignment process to assign families to a condition, many of our analyses, such as those done on learning tasks, the transfer task, and interview data, were descriptive or qualitative in nature. As such, the methods used for parts of this study limit overall generalizability. Future work would be necessary to replicate these results, particularly learning and transfer task results with larger samples.

Second, the assessment methodology used throughout this study does not provide causal evidence for the use of digital and non-digital CT learning resources to influence children's learning outcomes. Our efforts focused on comparisons between the intervention and control groups instead of comparing intervention group children pre- and post-intervention. Before this important work can be done, efforts are needed to refine the assessments of children's learning and to ensure high levels of reliability and validity.

Third, our current approach was originally driven by creating an unaligned assessment of the CT learning goals relevant for preschoolers versus creating an assessment that was aligned to the intervention itself. In the process, we learned a great deal about what preschoolers seem to be able to do and not do. However, we have come to realize that because the landscape of CT skills for preschoolers is a new area of study and current work, we do not know enough about baseline preschool CT skills to create an assessment that is not aligned to intervention work.

Our recommendations are as follows: (1) the new direction for CT assessment tasks should start with a foundation of clear, measurable goals or sub-goals upon which to include in the intervention, and (2) the assessment should align the tasks to the content covered in the intervention itself. This way, it is clear that children's learning of the intervention content can easily be ascertained.

Broader Implications

Very few studies have focused on how CT can be explored with young children. This study provides the building blocks to show that, through a combination of videos and hands-on activities, parents can generate meaningful experiences for preschool children to explore CT by leveraging their own personal interests and willingness to support these at-home learning opportunities. The evidence suggests that parents have varying levels of comfort in providing supports that enhance children's ability to use their CT skills. Further exploration of how CT is already a part of everyday activities and how certain types of support can enhance these learning opportunities could create higher levels of parent comfort and confidence.

This study has also suggested promising joint engagement strategies that parents can use to promote the use of CT Core Ideas, including the following:

- Helping children verbalize ordered processes
- Encouraging children to be flexible in their thinking and finding different ways to solve problems
- Helping children break down problems, including asking open-ended questions to encourage new thinking
- Slowing down the pace of activities to allow for productive struggle
- Giving children time to notice problems

Assessing young children's CT knowledge using hands-on tasks shows promise, but more work is needed to hone that approach. Future research is also necessary to identify the precise evaluative criteria that represent children's current abilities, which will support the development of a reliable, validated assessment of preschool CT.

Appendix: Study Design and Sample Characteristics

Recruitment

The EDC research team worked with early childhood education centers in New York, Massachusetts, and Rhode Island to recruit families for participation. Site administrators from each organization sent recruitment flyers to families of four- and five-year old children registered in formal preschool programs. Upon expressing interest in participation, families attended a study information session that provided an overview of the study, participation requirements, and the opportunity for parents to ask questions. If interested in the study, parents took part in an onboarding session, where they were assigned to condition (i.e., intervention or control). Participating parents also completed a pre-survey and received study bags that contained (1) a tablet (pre-loaded with videos and hands-on activities), (2) printouts of the hands-on activities, and (3) instructions for how to engage in the study activities. Families were able to keep the tablets as a thank you for their participation.

Sample Characteristics

A total of 108 families across 12 early childhood education centers in New York, Massachusetts, and Rhode Island participated in the impact study. They were randomly assigned to one of two groups: (1) the CT-intervention group, which consisted of *AHA! Island* videos and hands-on activities and (2) the control group, which consisted of literacy-based videos and hands-on activities. Of the 108 families, 54 participated in the intervention and 54 in the control group.

A smaller subsample of child participants were randomly selected to participate in a series of CT learning and transfer tasks, described in more detail below. Fifty-three children (n = 25 from intervention, n = 28 from control) were selected for participation. Children were relatively equal across gender (n = 25 males, n = 28 females). More four-year-olds participated in these tasks; however, this was to be expected due to the large sample of four-year-olds in the study sample.

Child and Parent Characteristics

The sample of 108 children was 48% male and 52% female for the intervention group and 52% male and 48% female for the control group. Children's ages were between 4 and 5 and was equivalent across both groups, with four-year-olds comprising 68% and five-year-olds comprising 32%. The majority of children (96% in both groups) spoke English as their first-language at home, with a few children who spoke Spanish (4% intervention, 2% control) or Chinese (2% control). Similarly across both groups, a vast majority of children (84% intervention, 80% control) were not part of an individualized education program (IEP). Only a few families reported their child received an IEP (9% intervention, 13% control).

The majority of caregivers were mothers (83%) in both the intervention and control groups, followed by fathers (11% intervention, 9% control), grandmothers (2% intervention, 4% control), and grandfathers (4% in intervention and control). The education background of the mothers varied across both the intervention and control groups:

- 8th grade or less: 2% intervention, 0% control
- Some high school: 11% intervention, 7% control
- High school diploma or GED: 31% intervention, 26% control

- Some college or technical school: 24% intervention, 31% control
- Associate's or technical degree: 9% intervention, 11% control
- Bachelor's degree: 7% intervention, 15% control
- Graduate or professional degree: 9% intervention, 9% control
- Education background unknown: 6% intervention, 0% control

As for the education background of fathers, reports varied much more between both groups:

- 8th grade or less: 11% intervention, 4% control
- Some high school: 11% intervention, 15% control
- High school diploma or GED: 39% intervention, 22% control
- Some college or technical school: 11% intervention, 26% control
- Associate's or technical degree: 6% intervention, 17% control
- Bachelor's degree: 9% intervention, 7% control
- Graduate or professional degree: 9% intervention, 2% control
- Education background unknown: 4% intervention, 7% control

The full set of participant demographics are reported in Table 8.

Table 8. Participant demographics (N = 108)

Family and Child Characteristics	Intervention *n* = 54	Control *n* = 54
Child's gender		
Male	48%	52%
Female	52%	48%
Child's age		
4 years	68%	68%
5 years	32%	32%
Child's ethnicity		
Hispanic/Latino	28%	18%
Black/African-American	30%	41%
Asian	13%	13%
White (Non-Hispanic)	15%	6%
Biracial	9%	18%
Other	5%	4%

Family and Child Characteristics	Intervention *n* = 54	Control *n* = 54
Child's language spoken at home		
English	96%	96%
Spanish	4%	2%
Chinese	0%	2%
Child with individualized education program (IEP)		
Yes	9%	13%
No	84%	80%
I don't know	7%	7%
Child eligible for National School Lunch Program (NSLP)		
Yes	70%	61%
No	4%	7%
I prefer not to say	2%	2%
I don't know	24%	30%
Caregiver's relationship to child		
Mother	83%	83%
Father	11%	9%
Grandmother	2%	4%
Grandfather	4%	4%
Mother's education background		
8th grade or less	2%	0%
Some high school	11%	7%
High school diploma or GED	31%	26%
Some college or technical school classes	24%	31%
Associate's or technical degree	9%	11%

Family and Child Characteristics	Intervention $n = 54$	Control $n = 54$
Bachelor's degree	7%	15%
Graduate or professional degree	9%	9%
Don't Know	6%	0%
Father's education background*		
8th grade or less	11%	4%
Some high school	11%	15%
High school diploma or GED	39%	22%
Some college or technical school classes	11%	26%
Associate's or technical degree	6%	17%
Bachelor's degree	9%	7%
Graduate or professional degree	9%	2%
Don't Know	4%	7%
Family receives housing assistance (Section 8)		
Yes	6%	17%
No	87%	74%
I prefer not to say	5%	5%
I don't know	2%	4%

***p<.001; **p<.01; * p<.05

Establishing Baseline Equivalence

To establish baseline equivalence, we compared the background characteristics of children and families to determine if any significant differences existed between the intervention and control groups. For this, we conducted chi-square tests of independence on all child and family characteristics. We found no differences between the groups for child's age, gender, ethnicity, language, or IEP ($p > .05$). Similarly, we found no differences for caregiver's relationship to the child, mother's education, and income proxies ($p > .05$). However, we found significant differences between the intervention and control groups for father's education background ($p < .05$)

Additionally, we included a series of questions on the pre-survey related to family media habits, coding experiences, and normal every day activities to determine baseline equivalence between both groups, which is provided in more detail below.

Family Media Habits

As illustrated in Table 9, families were asked for the number of times (e.g., less than once a week, once or twice a week, three to five times a week, and four or more times a week) they did six media-related activities with their child during a normal week. Families reported fairly the same across these five activities:

- Reading books together
- Playing educational games on a cell phone, tablet, or other device together
- Playing educational board games, card games, or puzzles together
- Going places where you can learn together, such as at a park, museum, or library
- Doing hands-on activities together to learn things

For example, for the activity "reading books together," the intervention and control groups reported roughly a third for each response of once or twice a week (32% intervention, 28% control), three or four times a week (32% intervention, 37% control), and five or more times a week (29% intervention, 31% control), with both groups reporting almost the same for "less than once a week" (7% intervention, 4% control). Chi-square tests of independence further revealed no differences ($p > .05$), between the intervention and control group for these types of activities.

However, for the activity "watching educational videos on a computer or TV together," chi-square tests showed statistically significant differences between the intervention and control groups ($p < .01$), with the control group watching with more frequency at three to five times a week (56%) compared to the intervention group (24%).

Table 9. Parents' reports on family media habits pre-intervention by condition (N = 108)

Coding Experiences	Intervention *n* = 54	Control *n* = 54
Read books together		
Less than once a week	7%	4%
Once or twice a week	31%	28%
Three or four times a week	31%	37%
Five or more times a week	30%	31%
Watch educational videos on a computer or TV together*		
Less than once a week	6%	6%
Once or twice a week	41%	20%
Three or four times a week	24%	56%
Five or more times a week	30%	19%
Play educational games on a cell phone, tablet, or other device together		
Less than once a week	9%	13%

Coding Experiences	Intervention *n* = 54	Control *n* = 54
Once or twice a week	26%	28%
Three or four times a week	37%	33%
Five or more times a week	28%	26%
Play educational board games, card games, or puzzles together		
Less than once a week	20%	22%
Once or twice a week	30%	35%
Three or four times a week	37%	28%
Five or more times a week	13%	15%
Go places where you can learn together (park, museum, library)		
Less than once a week	24%	31%
Once or twice a week	59%	56%
Three or four times a week	15%	6%
Five or more times a week	2%	7%
Do hands-on activities together to learn things		
Less than once a week	6%	0%
Once or twice a week	41%	39%
Three or four times a week	37%	48%
Five or more times a week	17%	13%

***p<.001; **p<.01; * p<.05

Coding Experiences

Families in the intervention and control groups were asked how much time their child spends playing with toys or games that help them learn to code (see Table 10). Thirty-five percent of intervention families reported that their child spent "no time" playing with toys or board games, such as Code-a-pillar and Robot Mouse, compared to 30% of the control group; 37% of the intervention group and 56% of the control group reported their child spent "some time"; and 28% of the intervention group and 15% of the control group reported they spent "a lot of time."

Chi-square tests showed no differences between the two groups for this activity ($p > .05$). However, chi-square tests indicated significant differences between the groups for time spent playing with games on tablets, computers, or cell phones that helped them learn how to code, such as Scratch Jr. and Kodable ($p < .01$), with 35% of the intervention group and 20% of the control group reporting "no time," 20% of the intervention group and 48% of the control group reporting "some time," and 44% of the intervention group and 31% of the control group reporting "a lot of time."

Parent-Child Activities

Across both intervention and control groups, the majority of families (90%–100%) reported that they agreed or strongly agreed that their child liked watching videos on a phone or tablet, doing hands-on activities with an adult, building with blocks or other materials, and making art projects (Table 11). Chi-square tests of independence revealed no differences between the groups ($p > .05$) for these activities. Table 11 further illustrates parents' reports for each activity.

Table 10. Parents' reports on family coding experiences pre-intervention by condition (N = 108)

Coding Experiences	Intervention *n* = 54	Control *n* = 54
Toys or board games that help your child learn how to code (e.g., Code-a-pillar, Robot Mouse, BeeBot, Robot Turtles)		
No Time	35%	30%
Some Time	37%	56%
A lot of Time	28%	15%
Games on tablets, computers, or cell phones that help your child learn how to code (e.g., Scratch Jr., Kodable, codeSpark Academy, Lightbot)*		
No Time	35%	20%
Some Time	20%	48%
A lot of Time	44%	31%

***p<.001; **p<.01; * p<.05

Table 11. Parents' reports on activities children like, pre-intervention by condition (N = 108)

Child Likes	Intervention *n* = 54	Control *n* = 54
My child likes watching videos on a phone or tablet		
Strongly Disagree	0%	2%
Disagree	0%	0%
Neither Disagree or Agree	7%	4%
Agree	28%	31%
Strongly Agree	65%	63%
My child likes doing hands-on activities with an adult		
Strongly Disagree	0%	2%
Disagree	0%	0%
Neither Disagree or Agree	0%	2%
Agree	48%	39%
Strongly Agree	52%	57%
My child likes building with blocks or other materials		
Strongly Disagree	0%	0%
Disagree	0%	2%
Neither Disagree or Agree	0%	2%
Agree	44%	37%
Strongly Agree	56%	59%
My child likes making art projects		
Strongly Disagree	0%	0%
Disagree	0%	0%
Neither Disagree or Agree	2%	9%
Agree	39%	44%
Strongly Agree	59%	46%

Methodology

To address the research questions, the research team collected data from multiple sources, including a parent pre-survey and post-survey, parent interviews, CT learning tasks with children, and, for children in the intervention group, a CT transfer task. Each of the measures are described in detail below.

Measures

Parent Survey

To assess differences between the intervention and control conditions on our target outcomes, the research team administered a parent survey developed by the EDC research team at the beginning and end of the six-week study to parents in both the intervention and control conditions. The pre- and post-surveys collected information on family engagement in science exploration, use of parent engagement strategies, perceptions of ability to support child's science learning, and joint media engagement. Additionally, the pre-survey included demographic questions about the child's sex, the respondent's relationship to the child, the child's age, the respondent's highest level of education completed, and the respondent's race-ethnicity. The post-survey asked for feedback on the *AHA! Island* intervention.

Parent Interviews

Researchers conducted parent interviews with a subsample of intervention group parents over the phone to understand more about parent use of and perceptions about *AHA! Island* learning resources. Eleven parents opted-in for interview participation. The interviews were designed to last approximately 20–30 minutes. The first part of the interview asked parents to describe their experiences with the videos and hands-on activities, the extent to which they felt their child had learned new things from the intervention, and any additional feedback about the intervention.

CT Learning Tasks

After the completion of the study period, a subsample of children were randomly selected to participate in a series of CT learning tasks to evaluate children's abilities in the areas of sequencing, debugging, and design process. Children were visited at their early childhood education centers and participated in a series of two assessment sessions. Below, we provide a brief description of the tasks comprising the assessment sessions.

Card Sequencing Task. In this task, the child was shown an assortment of nine cards and was asked to pick those that were involved in the everyday behavior of tooth brushing. The assortment contained a number of target cards (toothbrush and toothpaste, running water on brush, squeezing on toothpaste, brushing teeth) and off-target cards (hairbrush, washing hands, rubber duck). The child then was asked to put the selected cards in sequential order for brushing teeth. After the cards were in order, the child was asked to verbally describe the sequence.

Pizza Task. This task was intended to serve as a more hands-on version of a sequencing task. First, the child watched a short video of a pizza being made. Then, the child was shown an assortment of felt food ingredients, a play oven tray, and a cardboard box oven and asked to make a pizza. Throughout the task, the child was asked to talk about why they were making the pizza that way. After the pizza was made, to probe the child's understanding of the importance of certain ordered steps, the child was asked questions about the role of the crust in the sequence of making a pizza.

Bracelet Debugging Task. This task was created to provide children with a structured opportunity to engage in debugging strategies. In this scenario, the researcher told the child that they would be making two bracelets together and the bracelets had to look the same. The protocol took the child through a session in which the child was prompted to verbalize a plan for making two similar bracelets by creating a sequence using beads, comparing the sequences across the two bracelets, fixing a purposefully erroneous sequence in the assessor's bead tray, and comparing and correcting a stringing error in the researcher's bracelet.

Duplo Design Task. This task was designed to explore children's design process abilities. The child was presented with a set of Duplo building blocks and told to make a house for a character. The researcher then introduced a problem scenario asking the child to fix the house so that the character would not get wet from the rain. In the second problem scenario, the researcher asked the child to alter the house so that additional friends could fit inside for a birthday party. In both problem scenarios, children were observed to assess the extent to which they identified the problem, verbalized possible solutions, created solutions, tested these solutions, and improved their designs as a result of these tests.

CT Transfer Task

Robot mouse is a toy that children can program to move along a track and reach a destination (a block of cheese) using a set of arrow cards that correspond to arrow buttons on the back of the mouse. The track consists of a set of interchangeable green squares that enable the assessor to change the track depending on the demands of the task. The research team developed a protocol that researchers used to first explain the toy to the child and to guide children through several minutes of free play, two training trials, two target trials where the child had to get the mouse to a pre-determined location (a piece of cheese), and an open-ended trial where the child could create their own problem to solve. In the target and open-ended trials, researchers coded the session videos to evaluate the child's ability to make a plan for a series of actions using a set of arrow cards and then program the mouse based on that plan.

Analytic Approach: Parent Survey

Factor Analysis

Because there are multiple items on the parent survey that probe each outcome, we needed to combine multiple items to create a single score for each outcome. To do this, we conducted an exploratory factor analysis of all close-ended items related to our hypothesized constructs:

- Parent confidence in their ability to engage their child in CT
- Parent perceptions of their child's CT abilities

Because all items in this analysis are ordinal and incorporating them as is would violate the assumption that variables are continuous and normally distributed, we employed a principal axis factor analysis with a promax rotation using polychoric correlations. Polychoric correlations assume an underlying continuous distribution and allowed us to reduce the likelihood of underestimated factor loadings and biased estimates of standard errors. Importantly, because we did not test whether the theoretical constructs were separate factors, it is possible that some of the outcomes may be related. In other words, we cannot assume that parents experienced five different kinds of changes for each individual item. The factor analysis resulted in two scores—one for parent confidence and another for parents' perceptions of child CT abilities—which we then used as outcomes in our regression models to test the relationship between providing access to *AHA! Island* learning resources and parent outcomes. The items that comprised each construct appear in Table 12.

Table 12. Survey questions in each construct

Parent Confidence in Their Ability to Engage Child in CT Construct
I know how to teach my child computer science skills by helping him/her solve everyday problems.
I want to help my child learn skills that he/she needs for learning how to code later in life.
I am confident that I can help my child learn how to solve problems.
I am confident that I can help my child learn the skills that will prepare him/her to learn how to code when he/she is older.
Parent Perceptions of Child CT Abilities Construct
My child knows how to solve a problem by thinking about the steps needed and then doing them in order.
When something is not working the way my child wants, he/she can figure out if there's a problem and come up with a way to make it work.
When my child wants to make something new, he/she knows how to create it, then test it to see how well it works, and then use what he/she learned to improve it.
When my child has a problem, he/she can think creatively about how to solve it.
When my child has a problem he/she can keep trying until the problem is solved.

Regression

To assess the extent to which changes in the target outcomes between the beginning and end of the study varied between the intervention and control groups, we fit two separate multiple regression ordinary least squares (OLS) models with the post-survey outcome measures as the dependent variables and the associated pre-survey outcome scores as the covariates. We included a dummy-coded intervention indicator (intervention = 1; control = 0) as a covariate to measure differences between the intervention and control groups. To improve the precision of the model estimates and to account for the potential influence of demographic and background characteristics, we controlled for the following variables: ethnicity, mother/father education, child age, child gender, educational media viewing, and time with coding games. Finally, to test if differences between the intervention and control groups varied based on the initial outcome scores from the pre-survey, we included an interaction term of the pre-survey outcome scores and the intervention indicator. In the interest of model parsimony, we removed any covariates that were not statistically significantly related to the outcome at the $p < .10$ level. In the parent confidence model, child age, child gender, father's education, educational media viewing, and experience with coding games were removed. In the parent perceptions of child CT abilities model, child gender, mother's education, father's education, race, educational media viewing, and experience with coding games were removed.

Tables 13 and 14 display the regression estimates for the parent confidence and child CT ability models. In order to demonstrate evidence for our hypothesis that parents' confidence and child CT ability scores started high and were recalibrated after experiencing the study. We have also provided pre-post average scores for the items used for each construct in Tables 15 and 16.

Table 13. Regression coefficients for parent confidence model

	Beta	T-value
Intercept		-1.64
Condition	-.10	-1.12
Pre-survey	.56	4.58**
Black	.14	.90
Hispanic	.32	2.21
Asian	.19	1.53
Other Race	.20	1.50
Mother education	.18	1.96
Pre-survey x Condition	-.10	-2.61**

***p<.001; **p<.01; * p<.05

Table 14. Regression coefficients for child CT abilities model

	Beta	T-value
Intercept		.692
Condition	-.01	-.06
Pre-survey	.55	5.00***
Child age	-.12	-1.38
Pre-survey x Condition	-.18	-1.70

***p<.001; **p<.01; * p<.05

Table 15. Average pre-/post-item scores for parent confidence items by condition (scale = 1 to 5)

	Intervention Pre (SD)	Intervention Post (SD)	Control Pre (SD)	Control Post (SD)
I know how to teach my child computer science skills by helping him/her solve everyday problems.	4.00 (.87)	4.15 (.86)	4.04 (.87)	4.24 (.64)
I want to help my child learn skills that he/she needs for learning how to code later in life.	4.59 (.53)	4.33 (.82)	4.48 (.61)	4.52 (.61)
I am confident that I can help my child learn how to solve problems.	4.61 (.53)	4.35 (.85)	4.57 (.50)	4.48 (.61)
I am confident that I can help my child learn the skills that will prepare him/her how to code when he/she is older.	4.37 (.83)	4.19 (.93)	4.39 (.71)	4.26 (.92)

Table 16. Average item pre-/post-item scores for child CT ability items by condition (scale = 1 to 5)

	Intervention Pre (SD)	Intervention Post (SD)	Control Pre (SD)	Control Post (SD)
My child knows how to solve a problem by thinking about the steps needed and then doing them in order.	4.00 (.58)	3.98 (.88)	4.11 (.63)	4.00 (.73)
When something is not working the way my child wants, he/she can figure out if there's a problem and come up with a way to make it work.	3.98 (.63)	3.93 (.91)	3.89 (.79)	3.81 (.89)
When my child wants to make something new, he/she knows how to create it, then test it to see how well it works, and then use what he/she learned to improve it.	3.91 (.62)	3.91 (.85)	3.81 (.80)	4.00 (.73)
When my child has a problem, he/she can think creatively about how to solve it.	4.06 (.66)	4.02 (.90)	4.06 (.69)	3.98 (.71)
When my child has a problem, he/she can keep trying until the problem is solved.	4.09 (.62)	3.96 (.87)	3.94 (.76)	3.85 (.74)

Analytic Approach: Interviews

All interviews were audio-recorded and transcribed. The research team coded the interview data thematically, based initially on our research questions, and identified and summarized cross-cutting themes across each data source.

Analytic Approach: Learning and Transfer Tasks

Children's performance on each CT learning and transfer task was synthesized via several methods. First, the assessor followed an observation protocol to record children's performance in real-time at key steps in each learning task. Assessors also recorded children's needs for prompting to continue with the task. These observer notes were entered systematically into a Qualtrics data form and treated as a data source. Videos of children's performance on each task were reviewed by trained coders to capture evidence of children's target CT-related behaviors via a checklist of CT behaviors determined prior to data collection. The research team summarized the results of children's performance for each individual task. Descriptive information was used to determine whether evidence existed for differences in children's performance across intervention and control groups. Researchers describe children's typical performance on tasks and specific instances where children used CT behaviors in solving problems and/or completing tasks.

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