AHA! Island Media and Hands-On Activity Sets: A Formative Research Report

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Abstract

AHA! Island is a new project that uses animation, live-action videos, and hands-on activities to support joint engagement of children and caregivers around computational thinking concepts and practices. This research is intended to examine the extent to which the prototyped media and activity sets support the project's learning goals. Education Development Center (EDC), WGBH's research partner for the project, conducted a small formative study with 16 English-speaking families (children and their caregivers) to test out these media and activity set prototypes. During the in-person video viewing session, researchers showed children one of four possible media sets, each related to a CT concept, and engaged in an interview protocol immediately following viewing. During the hands-on activity session, caregivers reviewed a hands-on activity prototype, conducted the activity with their child, and participated in an interview upon completion. Following the activity session, caregivers were given a tablet with additional media and hands-on activities related to the same CT topic, and were asked to use these materials at home with their children over a one-week period. At the end of the week, a researcher conducted a phone interview to gather caregiver reflections on the at-home experience.

Keywords: computational thinking, Pre-K, formative research, informal

Introduction

Computational thinking (CT) is a systematic way of problem solving that can help support children's learning in a variety of subject areas (e.g., math, science). Referenced as "the new literacy of the 21st Century" (Wing, 2011), CT can help children recognize complex problems, understand when problems require deconstruction, use new problem-solving tools, and decide which tools to apply or adapt for a given problem.

Research suggests that early childhood is an ideal time to lay the foundation for computational thinking skills. To build a solid basis for problem-solving skills later in life, children ages 4 through 5 need early, introductory experiences to both learn and practice the skills necessary for CT (Bers, 2008; Gelman & Brenneman, 2004).

AHA! Island is part of *Digital Media and Parent/Child Engagement Resources to Increase Preschool Computational Thinking*, an iterative research and content development project that is examining how joint engagement with digital media and hands-on activities can support preschool children's early learning of CT. As part of the project, WGBH and EDC have collaborated to develop a learning blueprint to articulate a set of CT learning goals for preschoolers in non-programming contexts. WGBH is building on this blueprint to develop *AHA! Island*, a new media property that uses animated stories, live action videos, music videos, and hands-on activities to enhance children's understanding of CT.

EDC conducted a small formative study with 16 English-speaking families (children and their caregivers) to test four sets of media and hands-on activity prototypes, each revolving around one of the target CT learning goals (*debugging*, *design process*, *sequencing*, and *modularity*). The study began with an in-person session in which

children and their caregivers experienced one of the four different prototype media and activity sets, each comprising three videos and a hands-on activity. Afterwards, caregivers were given a tablet with additional media and hands-on activities related to the same CT topic, and were asked to use these materials at home with their children over a one-week period. Researchers collected data through observations and interviews.

This formative research will inform further development of the current prototypes and will support the development of additional media and hands-on activities. Data examining the usability and appeal around the at-home implementation of media and hands-on activities will help the project team create educational resources that maximize caregivers' capacity to support at-home STEM learning. Research also will be used to inform the field about factors that contribute to successful joint parent/child engagement in computational thinking.

Methods

Media and hands-on activities were tested with a diverse mix of New York City families with children ages 4–5, and their caregivers.

Participants

The sample for media observations (N = 16) included 12 girls and 4 boys, with the majority of children being 4 years old (range 51 to 68 months, with average age of 55 months, or 4 years and 7 months). Families were recruited primarily from early childhood programs that serve low-income families[1]. Children's caregivers were primarily mothers (n = 14), but one father and one grandmother also participated in research sessions.

[1] Of the three families that were recruited from outside center-based early childhood programs that serve low-income families, one family reported qualifying for free/reduced-price lunch; none of the three reported qualifying for housing assistance.

Fifty percent of families were self-reported as Hispanic or Latino, 31% as Black or African-American, 13% White, and 6% other. Half of the families (50%) reported that they speak both English and Spanish at home, and 31% reported that they speak only English in the home; 19% reported some other combination of languages, including Soninke and German. Participants also reported the educational levels of the children's mothers and fathers. Twenty-five percent (n = 4) of the children's mothers have a bachelor's degree; 19% (n = 3) have a graduate or professional degree; 19% (n = 3) have taken some college or technical school classes; 19% (n = 3) have an associate's degree or technical degree; 13% (n = 2) have a high school diploma, and one has an eighth-grade education or less. Twenty-five percent (n = 4) of the children's fathers have a bachelor's degree; 25% (n = 4) have a high school diploma; 13% (n = 2) have an associate's degree or other technical degree. One father has a graduate or other professional degree, one has some high school, and one was recorded as "Don't Know." One child had a known IEP.

Media and Activity Sets

Four different prototype sets of resources were developed, each focused on one of the following CT learning goals: *sequencing and algorithms*, *modularity*, *design process*, and *debugging*. Some of the resources also focus on promoting teamwork and persistence as part of the mindset for problem solving using CT. Each media set contained one 7-minute animated story, three 1.5-minute animated songs, one 1.5-minute live action video, and three hands-on activities. The animated stories and music videos were produced in animatic format (a prototype form of animation created by shooting successive sections of a black-and-white storyboard and adding an audio soundtrack) for the purposes of formative testing. The live action video appeared more like its final format, with child

actors modeling actions and participating in activities related to the target CT skill. Each media and activity set was supported by a short catchphrase to help scaffold the CT content for children and their caregivers. Brief descriptions of the learning goal areas for each media and hands-on activity set are included below.

- *Sequencing:* Media and hands-on activities emphasize situations in which the order of events is important when solving problems or accomplishing goals. “Step it out” is the accompanying catchphrase for the sequencing media and activity set.
- *Debugging*: Media and hands-on activities emphasize the use of a systematic process for fixing and improving solutions, including identifying the problem, brainstorming and applying solutions, and checking results. “Make it work” is the accompanying catchphrase for the debugging media and activity set.
- *Modularity:* Media and hands-on activities support the practice of breaking problems down into parts and identifying strategies for addressing each smaller problem component to accomplish a goal or solve the “big” problem. “Break it down” is the accompanying catchphrase for the modularity media and activity set.
- *Design Process:* Media and hands-on activities model the process for designing a solution to a problem. Specifically, individuals create a solution to the problem, test their solution, and then make improvements. “Create, test, improve” is the accompanying catchphrase for the design process media and activity set.

Data Collection

The study began with an initial in-person video viewing session, during which children and their caregivers explored three videos (one animated story, one music video, and one live action video) and one hands-on activity from one of the four different

prototype media and activity sets. Children and caregivers first watched the videos. Immediately following each video, the researcher asked the child a series of questions about the video. During the follow-up hands-on activity session, caregivers reviewed a CT hands-on activity prototype and conducted the activity with their child. Following the activity session, researchers interviewed the caregiver about their experience. At the completion of this initial in-person session, caregivers were given a tablet with media and two hands-on activities, and were asked to use these materials at home over a one-week period. Following this at-home trial, caregivers participated in a phone interview to reflect on their experiences.

Data Analysis

During each family's session, the researcher created a running record of observations from media viewing and hands-on activity testing. To support these notes, researchers videotaped the child media observations and caregiver/child activity sessions, and created audio recordings of the follow-up caregiver interviews. Researchers assigned items from each of the data collection instruments to one of the research questions of interest. Then the research team synthesized observation notes to create summary data across observation sessions. Recorded video or audio files were consulted to identify direct quotations from caregivers or children and to provide supporting evidence around engagement strategies, whenever appropriate. Researchers transcribed child responses to each question from the media observation protocol and identified parts of their responses that reflect comprehension of the plot or target CT content. Activity sessions were reviewed for evidence of target behaviors for each prototype. Members of the research

team coded caregiver interview responses for major themes as they relate to the research questions of interest.

Results

EDC combined the data from all sources to learn more about how the media and activity sets were used, and the extent to which they fostered child comprehension and appeal, child attention to CT concepts, parent/child engagement, and parent promotion of CT concepts. The following sections present findings as they relate to our five research questions of interest.

1. To What Extent are the Videos Comprehensible and Appealing to Preschool Children?

Across all four media sets, children found all three video formats (story animatic, music video animatic, and live action video) appealing. Researcher observations provided evidence that most children were excited to begin video viewing, and in almost all cases remained excited or agreeable to continue watching. Even in animatic form, the animated stories and the music videos appeared to consistently hold most children's attention through the duration of the viewing session. Live action videos also were appealing to children, but appeal was more variable based on children's behavior during viewing and observed level of attention.

Feedback from the at-home implementation provided further evidence of appeal, with all caregivers reporting that their child enjoyed watching the videos at home. When asked for evidence of enjoyment, many caregivers reported that their children were singing the songs even when the videos were not playing, and that their children wanted to keep watching the videos with or without the caregiver making the decision to view.

Children liked the monkey characters, and most had a favorite character. Many children made positive comments or exclamations to the researcher or to the caregiver about the monkey characters during viewing. When asked what they thought about the monkeys after viewing, children said things like, "They were happy," "They were smart," and "They are good builders." In addition, almost all children pointed to a favorite monkey when provided with a prop card, although they did not recall the monkeys' names without researcher prompting.

Caregivers also found the videos appealing. During the in-person observation sessions, researchers reported that nearly all caregivers appeared engaged periodically or throughout the in-person video viewing sessions. Examples of engagement included sitting quietly and watching the videos, commenting on videos, smiling and laughing, and moving to the beat of the music. In addition, in follow-up interviews, caregivers unanimously said that they liked the videos, reporting that they were educational, interesting, cute, descriptive, and enjoyable to watch.

Caregiver reactions to the monkey characters were more variable. Most caregivers mentioned that they liked the monkey characters, noting the appeal of their problem solving behaviors, singing, and their playfulness. Three out of sixteen caregivers made critical comments about the monkeys, for example, that they talk too fast or make negative facial expressions. Another caregiver said that she would prefer the characters be another type of animal because of the ways in which monkeys have historically served as a derogatory reference to African Americans. This caregiver, when describing her sensitivity, referenced a controversy in the national news at the time.

Videos fostered rich caregiver-child interactions. In the in-person setting, researchers observed that more than half of dyads (9 of 15) interacted throughout in-person video viewing sessions. Interactions were initiated by both caregivers and children, and included asking questions, making comments about on-screen activities, and looking at and smiling at each other.

Caregivers also reported high levels of engagement with the videos at home, with children watching between two to four of the four videos sent home on the tablets. All but one of the caregivers reported watching the videos alongside their child (in this case, a sibling watched with the child). Caregivers provided rich detail about what it looked like when they watched together. For example:

- caregiver and child watched the videos together, and then she asked her son about what happened in the video and what he learned after each one;
- caregiver and child watched the videos before dinner (with the daughter requesting to do it multiple days in a row);
- caregiver and child watched the three main videos together. The child watched and re-watched the songs multiple times independently, and talked about the monkeys outside of watching the videos;
- caregiver and child talked about what "step it out" means, and her daughter understood that that meant putting together the steps to solve a problem.

Children exhibited high levels of plot comprehension of videos from all four media and activity sets, particularly in the story animatic and live action videos. Researchers assessed plot comprehension by asking the children to recount what happened in the videos and examining their answers. When asked about the story

animatic they viewed, 13 of the 16 children were able to identify several of the major plot points in the story, particularly the problem that the monkeys were trying to solve. When asked about the live action videos they viewed, children demonstrated high levels of comprehension from most of the videos.

Children's responses to comprehension questions on the music videos were less detailed across media sets. When asked to recount what happened in the music videos, most children answered by repeating a lyric of the song or reporting on the actions they saw the monkeys performing (e.g., getting dressed, making sandwiches). One music video showed particular promise (*Create, Test, Improve* from the Design Process media set), with three out of four children able to recall the problem being solved, as well as the solution the monkeys used for solving their problem.

2. What Evidence Exists That Preschool Children Focus on the Core Concepts of CT During Video Viewing?

As with plot comprehension, researchers assessed children's understanding of CT by asking them to recount details from the videos and then analyzing their answers.

Researchers found that children's attention to CT content was present across all media sets, as evidenced by their recounting of specific problem-solving techniques. However, researchers found significant variation in children's understanding from video to video.

In particular, children displayed more consistency in the recall of specific techniques to improve a solution, as modeled in the debugging media sets, and the process for creating something new, as modeled in the design process media set. Children were less consistent in articulating connections to the CT content after viewing

the modularity and sequencing media sets. The following are a collection of takeaways for each CT content area's media set:

Sequencing. For the sequencing videos, researchers looked for evidence that children understood that the monkeys needed to solve a problem by thinking about the steps involved, putting the steps in order, and then carrying out the solution.

- Half of the children who viewed the **story animatic** understood the featured problem (e.g., the monkeys did not know how to put the steps to having a picnic in order). When asked explicitly about the steps involved in the monkeys' picnic, children's responses were limited and often vague in the details related to the sequence of events. One child, when asked how the monkeys fixed their steps, responded with the correct process: making the food, taking the food to the picnic, then eating the food. Another child said that the monkeys followed a set of steps, but the child's recollection of the steps was not as demonstrated in the video.
- After viewing the **music video**, half of the children said the monkeys were singing about "step it out," which was a main aspect of the song's lyrics as well as the CT catchphrase. However, when asked to say what "step it out" means, children struggled to define it, with one child confusing it with the act of walking (literal stepping). None of the children was able to articulate the steps modeled in the music video of an armadillo preparing to go to sleep (waggle, fluff the pillow, then leap).
- After watching the **live action video**, in which child actors create an ordered sequence of dance steps, children's responses were primarily focused on the child actors' dancing versus the sequencing that the actors were modeling through

dance. None of the children could articulate why it is important to keep track of dance steps.

Debugging. For the debugging videos, researchers looked for evidence that children understood that the monkeys needed to solve a problem by examining an unsuccessful solution and changing or adding a step to come up with a successful solution.

- All children understood that characters in the **story animatic** were trying to fix something (a batch of lemonade), which required multiple steps. Children also recalled that the monkeys added a step (adding sugar) in order to successfully make lemonade, although they struggled with recounting the exact sequence of steps the monkeys used in each attempt. Some children expressed an understanding that the monkeys engaged in a problem-solving thought process in order to check and change their steps. When asked what the monkeys did to check their steps, they responded, "they thinked about it" and "they think."
- After viewing the **music video,** researchers found that children understood that the monkeys were trying to fix something (one of the monkeys had trouble getting dressed). However, children recalled less of the CT-focused content, relaying more in their responses about the visible actions of the characters (getting dressed) than the problem-solving practices (putting clothes on in the correct order).
- After viewing the **live action video**, all four children were able to identify the problem faced by the child actors in the video (creating a specific shade of green paint), and most children successfully identified actions that the child actors took to solve it.

Modularity. For the modularity videos, researchers looked for evidence of children's understanding that the monkeys were facing a big problem, that they broke the big problem into smaller parts, and that doing so can make it easier or faster to solve the bigger problem.

- As expected, children expressed varying levels of comprehension; however the content appeared more challenging for children to grasp overall.
- After watching the **story animatic**, three of the four children expressed an understanding of the featured problem: The monkeys had to make a gift or make sculptures of flamingoes. Half of the children articulated some understanding of a problem decomposition process that the monkeys used for making the sculptures. These children talked about the monkeys dividing up the job into smaller responsibilities, and also articulated the reason for doing so: because it made the job of making sculptures easier or more feasible. Other children in this condition were limited to basic plot comprehension of the monkeys making a gift for other characters.
- After watching the **music video**, three children understood that the monkeys had to make sandwiches. Half of the children articulated that the monkeys needed to work together on a process for making more sandwiches. However, the children did not talk about the reasoning behind breaking the problem down into smaller component parts.
- After watching the **live action video**, all four children understood that child actors were painting a picture of a mural. Half of them understood that the child actors divided the problem into smaller parts, with each child tackling one part. One

child talked about the value of using this strategy, saying, “There was so much stuff to do and they couldn’t get it done. They broke it down and did it in different parts to get it done quicker.”

***Design Process*.** For the design process videos, researchers looked for evidence of children’s understanding that the monkeys wanted to make something, and that they had to create, test, and improve their design to successfully make it.

- After watching the **story animatic**, all children recalled something about the featured problem (the monkeys wanted to make a house for their stuffed elephant). In addition, children consistently understood that the first house the monkeys built was too small, and they had to build a bigger one. Children also were able to describe the process of testing and improving the house in various ways (i.e., “they got to make a bigger house because it was too small … they gotta think to see if they could do it.”)
- After watching the **music video**, children understood that the monkeys were making a go-kart. All but one child articulated that the monkeys identified a problem with their go-kart design and needed to make a change to the design for it to go faster.
- For the **live action video**, all four children understood the problem (the child actors were making costumes) and that the actors identified aspects of the costumes that could be changed, and then made improvements. Children in this condition also were observed to use language modeled across the videos, using both “test” and “improve” in their own responses, something that was not observed with children in other media and activity set conditions.

Additional insight into children's CT learning was gained from the at-home portion of the study. After exploring *AHA! Island* media on tablets at home for one week, all caregivers unanimously reported that they thought their child learned something from watching the videos at home. When asked to elaborate, caregivers explained that children learned new strategies for solving problems as well as some of the non-problem solving content (e.g., mixing colors, getting dressed) from the videos.

3. To What Extent are the Hands-on Activities Useable and Appealing to Caregivers?

Caregivers and children consistently showed signs of engagement and appeal during hands-on activity observation sessions. Researchers assessed engagement levels during activity interactions by observing caregiver and child behaviors. Nearly all caregiver and child pairs appeared to enjoy working on their assigned activity together. Across all four activities, researchers observed caregivers smiling, laughing, joking with the child and asking questions. Children also were observed to laugh, smile, respond excitedly to caregiver questions, and engage enthusiastically in response to caregiver prompts.

In many cases, caregivers were able to complete the activity's objective, with some activities being more successful than others. All caregiver-child pairs persisted with the activities either until they completed the objective or until the researcher stopped them at the maximum allotment of time. Two activities in particular were more successful (Monkey Bridge in the debugging set, and Monkey Story in the sequencing set) as compared to the others (Monkeys in a Row in the sequencing set, and Cards for

Everyone in the modularity set). All activities involved parent and child working together to complete a simple game or create a simple structure using household materials. (See next section for a description of individual activities.) In Monkey Bridge and Monkey Story, all caregiver-child pairs were able to successfully complete the activity's objective—some with more or less focus on the CT objective than others. However, with Monkeys in a Row and Cards for Everyone, nearly all caregiver-child pairs struggled with understanding the objective and, instead, altered the activity in ways that focused less on its ability to support CT learning.

Caregivers reported positive experiences with at-home hands-on activity implementation. All but one of the caregivers who did both activities said they spread them out over the course of the week. Ten out of 16 caregivers said that they initiated the activities, but that the child played some role in choosing when and how they did them. Caregivers liked the hands-on, interactive aspects of the activities and that they often provided enjoyable bonding experiences between them and their child. Activities dislikes were infrequent.

Caregivers reported very few barriers to at-home implementation. The most common barrier (reported by two caregivers during follow-up interviews) was that their child does not like to follow a set of highly scripted directions. This finding is consistent with feedback heard after the in-person observation sessions. Two caregivers, during follow-up phone interviews, reported that their children do not like to follow instructions. Individual caregivers mentioned other minor at-home implementation barriers, including issues related to the messiness of particular activities or to the preparation of real food as a part of the activity. Activities that came "ready to use," such as the card games or easy-

to-access materials seemed to be associated with the fewest number of implementation barriers.

Caregivers thought that, for the most part, the activity instructions were fairly easy to follow and interpret, making their at-home experience easy to implement. Some caregivers commented that some of the activity instructions could benefit from simplification to separate the overall goal from some of the details. Two parents specifically cited the Mix Up Dress Up as an activity with easy-to-follow instructions and visuals to help with activity implementation. Parents reported some confusion with other activity instructions. For example, in the Snack Shape Stacks activity, one caregiver thought that there was too much text so the main goal did not stand out. She suggested that activity developers make the main idea stand out more and that, underneath it, the activity can have more detail.

4. What Evidence Exists That Hands-on Activities, When Used During Co-engagement Between Caregiver and Child, Promote CT Concepts?

Caregivers and children demonstrated some evidence of engagement with CT concepts across all four observed activity prototypes. The strength of family engagement with the activity's specific CT objective was variable by activity. Below is a summary of how participating families met the activity's CT objectives, and how caregivers typically supported children during the learning process.

- *Sequencing (Monkey Story)*. This activity asked caregiver-child pairs to take a set of pictures and use details in the pictures to place them in a certain order and tell a story about what they see. All four families were observed to successfully place the pictures in the correct sequence; however, the child's level of engagement was often

limited, and for some families, a large portion of the activity was caregiver-led. Caregivers who encouraged the children and scaffolded their storytelling were most successful. Almost all of the caregivers supported the activity by using the "step it out" catchphrase during their talk with children about the activity.

- *Debugging (Monkeys in a Row).* In this hands-on activity, caregiver-child pairs were instructed to arrange a set of monkey cards in a row such that adjacent cards share at least one of two variable characteristics (color and clothing). The goal was for children to lay out the cards, and then engage in a debugging practice to correct any errors. Almost all of the caregivers used scripted prompts to have children point out the similarities and differences among the cards. However, almost all caregivers required researcher intervention before the end of the activity to point out that the objective was to get the monkey cards lined up into one row. For the one family that did create a successful line of cards, it took three attempts for the child to line the cards up into one row, since the child wanted to try matching the cards her own way and was not as interested in the goal of making one row of cards. When redirected, the child became frustrated and the caregiver had to redirect attention to encourage persistence.
- *Design Process (Monkey Bridge).* This activity asked caregivers and children to create a small bridge over a bowl of water, using the materials provided. Families were encouraged to test their design and make improvements, as necessary. All four families were able to complete the activity with a focus on the CT objective of creating a design for the bridge and testing it to see if it worked. Several caregivers were observed to use the associated catchphrases ("create, test, improve") during the

activity, particularly the use of "test" and "improve" as phrases to support children's actions during the activity. Caregivers also were observed to ask children questions as they engaged in the design process.

- *Modularity (Cards for Everyone).* This activity asked caregivers and children to identify a process for making multiple greeting cards in a more efficient way than making them one at a time. Several caregivers requested support from the researcher before testing the activity, asking about the objective or how many cards they were required to make; still, all but one caregiver missed the fact that the goal was to make four identical cards using an efficient process. Some families made multiple cards that looked dissimilar and others attempted to make similar cards but could not make four in the prescribed amount of time. Two caregivers were observed to use some of the scripted prompts and the modularity catchphrase ("break it down"). One family did use a process for breaking the card down into parts and sharing the responsibilities, taking time to discuss how beneficial it is to break down a problem. For example, after the child "assigned" different parts of the card-making process to herself and her caregiver, the caregiver said, "We can break it down, right? Just like the monkeys did?" The caregiver then said, "I cut, and you ..." and the child finished the sentence with "color." The child then said, "This is my first time ever having a problem. I never had a problem before." The mother then asked, "So how are we solving the problem?" The child responded by saying, "By breaking it up, because I color and you cut and that way we can get it done faster. We work together on different things." This is one example of the richest interaction observed from this

experience, showing the possibility when the caregiver attends to the activity's objective.

5. What Factors Work Together to Support or Impede Effective Use of the Caregiver/Child Engagement Resources?

During conversations with caregivers, researchers noted that caregivers consistently mentioned the appealing nature of the resources as a factor that supported their continued use of the materials at home. Some caregivers noted that the qualities of certain hands-on activities supported deeper joint engagement.

Appeal

During follow-up interviews, caregivers stated that the appeal of the resources supported continued viewing and engagement at home. Caregivers reported that the appeal of the videos encouraged them to continue watching videos together with their children at home. Caregivers noted that children would ask about watching the videos, sing songs from the videos even when they were not playing, and would discuss the projects that they did during hands-on activity time with other family members, Caregivers also reported that the hands-on activities were appealing, particularly because they offered opportunities to bond with their children.

Use of the resources was supported by caregivers' appreciation for their educational value. Caregivers almost always thought the resources helped their child learn something. Sometimes they identified the educational goals as the target CT problem-solving strategies the resources were intended to address (like helping them talk about steps, or putting things in order), while at other times, particularly for the hands-on

activities, they pointed to secondary learning goals (like learning to set a table, or learning about balance when making a mobile).

Some caregivers provided evidence that the videos and activities reinforced each other and helped children make connections to real-world problems. For example, one parent reported that the hands-on activity they did as a part of the observation (Fruit Kebab Flowers) helped the child better understand the educational content from the videos and see its real-world applications: "The activity helped (the child) connect with what the videos were teaching. The activity helped to see that she could use different suggestions and incorporate them in her own way."

Researchers also asked caregivers about their understanding and interpretation of the CT catchphrases used across the activities. **Generally, caregivers reported that they understand what catchphrases meant and thought that these skills are important for their children to learn.** When asked to elaborate why they are important, caregivers frequently said that these skills would help children approach problems in different ways and provide them with strategies for solving problems later in life.

Joint Engagement Support Factors

Caregivers who encouraged their child to lead or collaborate on parts of the activity were most successful in engaging with CT. For example, on the sequencing activity (Monkey Story), some caregivers were very prescriptive that the child simply needed to place the picture cards in chronological order, whereas others facilitated the activity in a more open-ended way to allow the child to explore the pictures, describe what they saw, and create a story. Similarly, caregivers were quite variable on the design process activity (Monkey Bridge). Two caregivers let the child take the lead some of the

time, trying out their ideas and making suggestions on how to improve the bridge. Another caregiver took the lead on doing more of the bridge building, but had the child tell him what to do. Another caregiver led more of the activity, but allowed the child to participate in tasks such as taping pieces together. Across activities, researchers observed that the more children were engaged in helping or leading the activity's actions, the more opportunities they had to engage with the CT content.

Activities that give the child agency were most successful in getting families to stick with the activity all the way through to the end. For example, in the modularity activity (Cards for Everyone), none of the caregiver-child pairs was able to get to the point where they made all four cards using a systematic process. Some children did not want to make a card using the suggested design, and the caregiver altered the activity to allow children to make different kinds of cards, thus eliminating much of the CT-related practice. During the debugging card game (Monkeys in a Row), caregivers sometimes deferred to the child on how they wanted to play with the cards, allowing them to play more of a matching game than focusing on the goal of putting the cards in a row. Removing the objective of assembling the cards into one row, and fixing the ordered solution of cards in the row eliminates much of the CT skill practice. One caregiver, during a follow-up interview, explicitly said that her child "does not like to be told what to do."

Conclusions and Recommendations

From the findings presented in this report, the project team has assembled a set of recommendations to support further development of digital media and hands-on activities to promote the development of computational thinking skills. These recommendations

reflect what we have learned from observing children as they viewed video prototypes, and what was learned from hands-on activity observations and follow-up caregiver interviews. We believe that these recommendations may have broad implications for educational resources intended to teach computational thinking to young children.

Recommendations for Media

- Since children seemed to clearly understand both the plot and the major CT takeaways from the debugging and design process media, future resources should be modeled after these stories, music videos, and live action videos in terms of pacing and content. These stories have comprehensible, appealing storylines with room for the characters to notice something that is causing a problem, discuss the problem and how they might solve it, and demonstrate the process for how the CT strategy aids the problem-solving process.
- There are many possibilities as to why children may have had a hard time with the format of the music videos (for example, length of video, the fact that it is an animatic). Additional research would be necessary to better understand children's difficulties with this format in its current animatic form. However, the design process music video yielded promising evidence that children are able to understand the content in the short amount of time, even in its prototype format. The development team could consider this a successful prototype in its animatic stage that supported children's understanding of the CT concept.
- While children were able to grasp the meaning and even use some of the catchphrases ("create, test, improve" and "break it down," in particular), other catchphrases were somewhat challenging, particularly those using the word

"steps." Find ways to emphasize the meanings of the CT catchphrases so that they serve as meaningful triggers to the application of the skill in real-world problem solving. In addition, consistently applying each catchphrase across media formats (story animatic, music video, and live action video) will increase children's opportunities to understand the meaning of these phrases.

- Modularity seemed to be the most difficult CT concept for children to recall from the media content. While a few children recounted information from the media about the value of breaking a problem down into parts, this recall was less consistent as compared to children's responses in other conditions. Sequencing was also challenging, but children seemed better able to grasp the concept of a series of ordered steps than they were able to consistently see the value of problem decomposition for efficiency. Consider revisiting the modularity learning goal and its emphasis on efficiency.

Recommendations for Hands-On Activities

Consistent with the approach already taken by this set of hands-on activities, future resources should

- use basic household materials and require minimal preparation for setup and cleanup before starting the activity;
- include a simple, concise introduction to the big CT idea to ensure that caregivers understand the critical ways that the problem solving (and CT skill) are being practiced. Follow this introduction with step-by-step visuals or short instructions whenever possible;

- create activities that allow for the child to have some agency in the way in which a problem is solved. *Monkey Bridge* provides an excellent example of how materials are suggested, but children have flexibility in determining the design.
- consider how various parenting styles may result in more or less child agency in engaging with the problem. For example, caregivers with a more authoritarian approach to parenting may always exert more control over activities. Consider how these caregiver characteristics, which are difficult to change without one-on-one intervention, may affect the family's ability to engage in a CT learning opportunity.

Consistent with findings from the media sessions, modularity seemed to be the most difficult CT concept for both children and their parents to work on. During the in-person session, caregiver-child pairs were observed making different kinds of cards. Some focused on problem composition, but all families missed the focus on efficiency as a value during card making. When discussing at-home experiences, caregivers sometimes discussed modularity activities as a set of steps, rather than the value of breaking down a problem. Activities under the modularity learning goal should be revisited in an attempt to identify the critical CT connections.

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