

Engaging Children and Families in Active, Environmental Science Learning through Digital Media

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ABSTRACT

An independent evaluation of an environmental science program that combined digital media with hands-on activities (called *Plum Landing*) was conducted in 2020. The study included 32 families with six- to eight-year-old children. The evaluation assessed the extent to which the program was successful at promoting connectedness to nature, specifically through teaching environmental science content and encouraging active nature exploration among participating families. The evaluation found that families spent more time outdoors exploring nature and more time being physically active as a result of using Plum Landing. In addition, children's environmental science content knowledge increased, and parents reported an increase in children's nature-related habits of mind (i.e., questions you need to ask when investigating an ecosystem) after using Plum Landing. Children's interest and attitudes towards outdoor activities were moderate to high at pre-test and did not change over time. Overall, families were very positive about their Plum Landing experience and reported they would continue to use the program and recommend it to other families. This study provided evidence that digital media accompanied by hands-on activities has the potential to support families in learning about and becoming more connected to nature while together at home.

Keywords: media, family, environmental science, STEM learning, family science

All across the globe, communities are grappling with the need to prepare for and respond to climate change. The United Nations calls climate change "the defining issue of our time," and the Intergovernmental Panel on Climate Change points to shifting weather patterns, rising sea levels, and melting ice caps as evidence of a profound environmental upheaval that is threatening ecosystems from the Amazon rainforest to the Arctic tundra (Qin, 2013). Acknowledging that children are the next generation of change agents, it is imperative to instill in them an understanding of the workings of our natural environment, as well as a sense of stewardship, if we hope to chart a new course.

Nature connectedness is good for children and for the planet

Recent research has demonstrated that positive experiences with nature, both structured and unstructured, can build children's environmental knowledge and skills and provide opportunities for positive emotional experiences that foster a sense of connection with the environment (Ballard, Dixon, & Harris, 2017; Clayton et al., 2011). This sense of environmental connectedness can, in turn, establish children's behaviors related to environmental

stewardship for improving ecological health (Barrable & Booth, 2020). Recent research also reveals that environmental connectedness is likely a much more powerful predictor of stewardship than environmental knowledge alone (Otto & Pensini, 2017).

At the same time, research shows that spending time in nature can contribute to children's health and well-being. Benefits of time spent outdoors include reduction in obesity, anxiety, ADHD symptoms, and stress, and increases in immune system functioning (Cleland et al., 2008; Taylor & Kuo, 2011; Park et al., 2009; Li et al., 2007; Li et al., 2009). Nature connectedness is also generally linked with a decline in behavioral and emotional issues in children (Barrable, 2019).

Thus, for both environmental health and child health reasons, it is vitally important to provide our children and youth with opportunities to spend more time outdoors engaging in educational, nature-based activities.

Nature connectedness can start at home

Nature-based, environmental science activities may be effectively provided by schools, nature programs, and other out-of-school-time organizations (Paulsen & Andrews, 2019; Paulsen, 2013). However, parents and children also have an opportunity to learn together at home. At-home learning is especially salient at the time of this writing—during the COVID-19 pandemic when most families around the world are facing an extended period of sheltering-in-place and virtual schooling.

Prior research indicates that family engagement in at-home STEM activities can promote joint exploration of core disciplinary ideas and practices (Lavigne et al., 2020; Silander et al., 2019). Having a parent teach or facilitate learning at home can be powerful, as it lays the necessary educational groundwork for a child's confidence and proficiency in other settings such as classrooms (McClure et al., 2017). Moreover, recent studies have demonstrated that parents' own nature connectedness is a more significant predictor of nature connectedness in their children, even more so than access to or time spent exploring nature (Barrable & Booth, 2020; Passmore, Martin, Richardson, White, Hunt, & Pahl, 2020).

Media may help support parents in facilitating nature connectedness at home

Despite the potential for joint exploration, many parents are not confident in teaching their children science. Research suggests that parents are more supportive of children's reading and math skills than science, due to their personal perception and self-efficacy regarding science (Cardoso & Solomon, 2002; Solomon, 2003). Studies have also found that parents from low-income communities in particular cite lack of ideas and resources as a barrier to doing science with their children (Stiles & Silander, 2020; Goldstein et al., 2018).

Media can play a critical role in giving parents ideas and structure for exploring STEM with their children, and helping parents develop the confidence they need to teach their children. A recent study by Sheehan et al. (2018) compared learning among young children with parents who had STEM careers versus parents who did not, and found that educational media connected families to information and activities that they would not otherwise have access to, and supplemented their child's knowledge of math and science, regardless of the parent's understanding of STEM. Additional studies have found that learning programs that include enjoyable and interactive educational media can augment a child's learning experience by keeping both parent and child engaged (Lavigne et al., 2019; Lavigne et al., 2020). Interactive technologies like digital games and mobile apps may play a unique role in enriching cognitive development and encouraging the growth of skills like problem-solving and nature connectedness in young children: because they often provide opportunities for parent and child to collaborate, these technologies encourage the child to discuss and share what they have learned. Additionally, instructional apps tailored to families can not only provide education for children, but can benefit parents by providing background on STEM content and highlighting strategies for engaging their children (Kucirkova & Falloon, 2016; Silander et al., 2018).

Plum Landing

One media-based project developed to teach young children about nature and inspire them to take care of their environment is Plum Landing. Plum Landing is a digital media PBS Kids series that is funded by the National Science Foundation. The project uses videos, games, apps, and hands-on activities to motivate six- to eight-year-old children to investigate the natural world. Over the last several years, content developers from WGBH Boston and researchers from the Education Development Center (EDC) used an iterative research and design process, during which the project team went through multiple cycles of implementation and revision, to create the Plum Landing Explore Outdoors Toolkit (Goldstein et al., 2018). The Toolkit includes digital media resources (animated stories, live-action videos, an online badging system, a digital game, and an app for families), hands-on science activities, and support materials for parents, caregivers, educators, and program directors—all developed to help urban children reap some of the educational, mental, and physical health benefits of actively exploring nature. In 2020, Concord Evaluation Group (CEG) conducted an independent evaluation of Plum Landing. The evaluation included a self-directed, at-home study, which is the focus of this article.

Methods

Study Objectives

CEG conducted an independent evaluation of the Plum Landing Explore Outdoors Toolkit in the spring and summer of 2020. The evaluation was designed to assess the extent to which an at-home family exploration program using the Plum Landing Toolkit (Plum Landing) materials contributed to children's overall feeling of connectedness to nature, defined for the purposes of this study as observing enhanced children's environmental habits of mind (i.e. questions you need to ask when investigating an ecosystem); motivation to explore the environment; improved attitudes about nature; and increases in environmental science knowledge. This definition of connectedness used for this study builds upon and expands the definition of connectedness used in other studies in that it acknowledges the importance of affective, cognitive, and behavioural aspects of connectedness, while, within this framework, highlighting the importance of motivation and environmental knowledge (Barrable & Booth, 2020; Otto & Pensini, 2017). Our definition of nature connectedness, for the purposes of this study, includes the experiential aspect of enhancing children's environmental habits of mind (i.e. questions you need to ask when investigating an ecosystem); the affective aspects of motivation to explore the environment and improving attitudes about nature; and the cognitive aspect of increasing environmental science knowledge. In addition, CEG investigated the extent to which Plum Landing supported parents in spending more time exploring nature with their children.

Study Design

The study was designed to collect data from a sample of 32 families who used Plum Landing over a period of two to four weeks. Upon enrollment in the study, parent-child dyads (hereafter referred to as "families") participated in video conference calls with a CEG senior researcher who conducted a pre-test interview with each family. After conducting the pre-test interview, CEG instructed families to explore Plum Landing with specific program instructions about which activities and media to use (all materials were publicly available at no cost from the Plum Landing website). The program instructions asked parents to begin by watching a two-minute video about how to explore nature with their children and a one-minute video designed to introduce them to the Plum Landing story and characters. Next, CEG encouraged parents to review a series of training tips for parents available via video or downloadable PDF. Families were then asked to try out five different explorations (each consisting of an introductory animated video and follow-up outdoor activity) over the course of the study. Finally, families were also encouraged to use a digital game highlighting nature in the city, a mobile app designed to build the habit of active outdoor nature exploration, and a badging activity in which families complete outdoor missions in order to receive digital rewards (collectable, virtual "badges").

When families were done with the program, they contacted CEG. At this point, parents completed an online survey and scheduled their final family interviews. The final family interview enabled CEG to compare responses across time and look for trends in their children's environmental science-related habits of mind, motivation, attitudes, and

content knowledge, as well as the parent's motivation, comfort, and time spent exploring nature with their children. In addition, the final interview enabled CEG to gather evaluative feedback on the Plum Landing resources.

Instruments

Although measures have been developed to assess the affective, cognitive, and behavioral aspects of nature connectedness among adults (e.g., Nisbet, Zelenski, & Murphy, 2009), fewer measures have been developed for children, and those that we found focused primarily on the affective dimension (e.g., Cheng & Monroe, 2012; Richardson et al., 2019). To ensure that our assessment covered all aspects, and to ensure that the assessment was aligned to the intervention, we decided to develop custom measures for the evaluation.

The pre-test interviews were semi-structured interviews designed to capture data on children's baseline environmental habits of mind (parent-reported), motivation to explore the environment (self-reported), attitudes about nature (self-reported), and environmental science knowledge (objective measure of content knowledge developed specifically for the current study).

The post-test interviews were also semi-structured interviews designed to capture the same data collected in the pre-test interviews, plus, parents were asked about how they implemented the program components and families were asked to evaluate their experience using the program materials.

Recruitment

CEG reached out to over 2,000 families nationwide who have previously indicated an interest in participating in a research study with CEG to let them know about the upcoming study. Families that were interested in participating completed a screening survey online to determine their eligibility. Participants were qualified for the study if they had: (1) At least one child between the ages of six and eight years old, (2) access to the internet, and, (3) the ability to communicate in English for the purposes of participating in video conference interviews. Families were offered an incentive of \$100 to participate in the study. Parents provided informed consent for their family's participation in the study. The study plans and procedures were reviewed and approved by an independent institutional review board.

Participants' Backgrounds

A total of 32 families participated in the study (see Table 1). Participants were from 19 different states and all regions of the country. Children's ages ranged from six years old to eight years old, with 13 six-year-old participants, 12 seven-year-old participants, and seven eight-year-old participants. Fourteen of the participants were female, and 18 of the participants were male. Six of the families reported their household income as low income, 14 of the families reported low to middle incomes, and 12 of the families reported they had middle incomes (we allowed families to define income levels in comparison to other families they know, rather than using strict numeric criteria).

Of the **children's** ethnicities, 13 were white or Caucasian, seven were Black or African American, two were Asian, two were Indian or Middle Eastern, two were Latino/a, and three parents preferred not to respond to this optional question. Of the **parents'** ethnicities, 11 were white or Caucasian, nine were Black or African American, four were Latino/a, one was Asian, one was Indian or Middle Eastern, and five parents preferred not to respond to this optional question.

Table 1
 Family Background and Demographic Characteristics (n=32)

Characteristics	n
<i>Child Age</i>	
6 years old	13 (40.6%)
7 years old	12 (37.5%)
8 years old	7 (21.9%)
<i>Child Sex</i>	
Male	18 (56.2%)
Female	14 (43.8%)
<i>Child Race/Ethnicity</i>	
White or Caucasian	13 (40.6%)
Black or African-American	7 (21.9%)
Asian	2 (6.3%)
Indian or Middle Eastern	2 (6.3%)
Latino/a	2 (6.3%)
Prefer not to respond	3 (9.4%)
<i>Parent Race/Ethnicity</i>	
White or Caucasian	11 (34.4%)
Black or African-American	9 (28.1%)
Latino/a	4 (12.5%)
Asian	1 (3.1%)
Indian or Middle Eastern	1 (3.1%)
Prefer not to respond	5 (15.6%)
<i>Self-reported Household Income Status</i>	
Low to middle income	14 (43.8%)
Middle income	12 (37.5%)
Low income	6 (18.8%)

* Parents could choose more than one race or ethnicity so the totals may be greater than 100%.

Family Science and Nature Experience

During recruitment, most families reported having only some to little science activity experience: 23 of the 32 families (72%) said that they only did “some” science activities together; six reported that they did not do any science activities together at all (19%), and only three families reported that they did “lots” of science activities together (9%).

In addition, all 32 parents (100%) reported that they had access to at least some form of nature in their neighborhood, anything from small gardens, trees, and plants to parks or trails. Five parents reported that their children were not always able to play outdoors due to fears that their children might get hurt (16%). Three parents (one each) indicated that the following were obstacles for their children: nature was uncomfortable for them, gangs or crime made outdoors dangerous, and health reasons. Other reasons cited by parents included: the current pandemic emergency and weather.

Analyses

Analyses of quantitative data mainly consisted of descriptive statistical analyses such as measures of central tendency. When applicable, inferential statistical analyses were performed. For example, a t-test was performed to analyze differences in environmental science content knowledge at post-test versus pre-test. Finally, open-ended responses were analyzed by reviewing the data using thematic analysis.

Program Implementation

How Families Used Plum Landing

We asked parents to report how they accessed the Plum Landing resources and incorporated them into their daily routines (hereafter, when we use the term “Plum Landing,” we are including all the components of the Plum Landing Explore Outdoors Toolkit—the introductory videos, parent tips, animated stories, outdoor activities, app, badging feature, and game that families were directed to use at the beginning of the study). We also asked parents to report what devices they used to access Plum Landing throughout the study. Twenty-five (78%) reported using a computer or laptop, 22 (69%) reported using a smartphone, and eight (25%) reported using a tablet. Parents could report more than one device.

All but one of the families (97%) reported that when they watched the videos, they did so indoors. Conversely, all but one of the families (97%) reported that when they did the hands-on activities, they did so outdoors, as intended. One parent reported that their child was not interested in going outdoors to do the activities, so they did the activities that could be done indoors in their home.

Families reporting engaging with Plum Landing in various ways. For example, some families made it part of their daily routine during the study, following roughly the same schedule each day (e.g., trying Plum activities after breakfast or lunch or during a sibling’s naptime). Other families took a less structured approach, doing Plum activities only when they had time. Some parents and children read through the resources independently before trying the activities together while other families read through the resources together. Some families let their children drive the engagement with Plum, including explaining it to other family members, while other families relied on parents to drive the activities with children in a more passive role.

Program Fidelity

Families demonstrated high levels of program fidelity or adherence to the study instructions, with families trying at least four of the five outdoor activities together and each of the activities being tried by 74% to 96% of family dyads. Interesting to note was that a couple of families occasionally let their children do the outdoor activities alone despite being specifically instructed and encouraged to do them together. These were usually cases of children wanting to

do them alone or an unplanned interruption from a sibling that took the parents' attention elsewhere. But, these instances were rare. In addition, two parents reported doing the activities alone because they wanted to test them out, but never ended up doing them with the children for various reasons (usually lack of time).

With respect to co-viewing of the media, not surprisingly, all the parents and children watched the short video intended to introduce the Plum Landing characters together, while parents were more likely to watch the additional introductory material geared toward parents alone or with their children. Most families reported watching the content-related videos together. Each of the videos was viewed by 80% to 96% of family dyads.

Slightly more than half of the sample reported that they tried out the additional, optional media, including the app, badging feature, and the game. Between 77% and 88% of families used these media together, rather than just the child alone or the parent alone.

Results

Children's Habits of Mind

We asked parents to rate the extent to which they had observed habits of mind related to science and nature learning (i.e., questions you need to ask when investigating an ecosystem) in their own children before and after using Plum Landing, as outlined in Table 2. At pre-test, parents rated whether they observed their children using environmental science habits of mind on a scale of 1 (strongly disagree) to 5 (strongly agree). On average, parents reported moderate levels of agreement between 3.34 and 3.97 (out of 5.00) with respect to whether their children exhibited environmental science habits of mind. Parents were most likely to report that their children exhibited an interest in going outside than other habits of mind. Parents were least likely to report that their children were showing curiosity about nature or asking questions about nature.

At post-test, we asked parents whether their children were exhibiting these habits less than, as much as, or more than before using Plum Landing. We did not ask them to use the rating scale again; we only asked them to report changes, if any. After using Plum Landing, most parents reported increases in their children's environmental science habits of mind. Many reported their children showed an increased curiosity about nature (66%) and an increased desire to share new information and ideas about nature (78%). Approximately half of parents reported that their children were now asking more questions about nature (47%), noticing things about nature (53%), and expressing more of a desire to go outside (56%).

Children's Motivation and Attitudes

One way that we assessed children's motivations and attitudes related to science and nature was to ask them to indicate the degree to which they enjoyed general science and nature activities—with a "thumbs-up" if they enjoyed each activity, a "thumbs-down" if they did not enjoy it, or a "thumbs in the middle" if they were neutral about an activity (see Table 3).

We found no appreciable change in reported enjoyment levels across a number of activities from pre-test to post-test. At pre-test, the average proportion of positive (thumbs-up) responses across all activities was 71%. The activities with the most positive responses were playing outdoor games (89%) and playing sports (89%). The activity that got the least positive response from participants was collecting rocks and leaves (46%). Most activities were reportedly enjoyed by more than half of the children who participated. It should be noted that a total of 28 out of 32 children answered this question as some of them were too shy or too distracted during our pre-test interview. At post-test, the average proportion of positive responses was still 71%. The activities rated highest were still playing outdoor games (88%) and playing sports (75%). The activity rated lowest was still collecting rocks and leaves, though more children reported enjoying this activity at post-test than at pre-test (53% versus 46%).

Table 2
Children's Habits of Mind Before and After Plum Landing (n=32)

Habit	Pre-Test Average (sd)	Children doing this a little more at post-test Count (%)	Children doing this a lot more at post-test Count (%)
Asking questions about nature (e.g., "What animals and plants live here?" or "How did this plant start growing here?")	3.41 (0.71)	11 (34.4%)	4 (12.5%)
Noticing things about nature (e.g., that bees are usually found near flowers, or that puddles in the sun dry up faster than puddles in the shade)	3.53 (0.57)	10 (31.3%)	7 (21.9%)
Showing curiosity about nature (e.g., asking why certain animals and plants look the way they do, or following an ant to see where it goes)	3.34 (0.70)	17 (53.1%)	4 (12.5%)
A desire to share new information and ideas about nature (e.g., telling me something he or she learned in school, or describing an interesting thing they saw in nature)	3.72 (0.52)	19 (59.4%)	6 (18.8%)
Asking to go outside a lot	3.97 (1.00)	12 (37.5%)	6 (18.8%)

Table 3
Children's Attitudes towards Various Activities Before and After Plum Landing

Activity	Thumbs-Up Pre-Test Count (%) n = 28	Thumbs-Up Post-Test Count (%) n = 32
Play outdoor games like hide and seek or tag	25 (89.3%)	28 (87.5%)
Look for small animals and birds	23 (82.1%)	26 (81.2%)
Learn about animals, plants, weather, or water	23 (82.1%)	26 (81.2%)
Play a game indoors*	20 (71.4%)	25 (78.1%)
Play sports	25 (89.3%)	24 (75.0%)

Take a walk outdoors	20 (80.8%)	24 (75.0%)
Look at trees, plants, flowers	20 (71.4%)	24 (75.0%)
Take pictures of nature	15 (53.6%)	19 (59.4%)
Read a book*	17 (60.7%)	18 (56.2%)
Look for bugs	14 (50.0%)	18 (56.2%)
Collect rocks or leaves	13 (46.4%)	17 (53.1%)

*We included indoor or location neutral activities so that children who weren't interested in outdoor activities would have something positive to respond to.

To further assess children's attitudes about nature, we asked children to use one word to complete the following sentence, "When I am outdoors in nature, I feel ____." Before using Plum Landing, 26 out of 28 (93%) of the words children used to complete the sentence were positive words such as "happy" or "good." After using Plum Landing, 30 out of 32 (94%) of the words children used were positive. This was a non-significant improvement, but already most of the children were positive at pre-test so there was little room for growth.

To assess children's attitudes towards science at both the pre-test and post-test, we asked children to tell us whether they liked science. Even though there was an increase in the proportion of children who replied in the affirmative at post-test, the differences were not statistically significant.¹ At pre-test, 21 out of 28 (75%) of children reported that they liked learning about science. At post-test, 26 out of 32 (81%) reported that they liked learning about science.

To further explore the question of whether Plum Landing helped children develop more positive attitudes towards nature, we looked for evidence that the program helped children feel more connected to the outdoors and gave them ideas of new things and places they could explore in nature. So, at post-test we asked children, "Did Plum Landing help you think of new things you can do outside?" and "Did Plum Landing help you think of new places you could explore in your neighborhood?" and "Did Plum Landing make you feel more or less like learning about science?"

When asked if Plum Landing influenced their ideas of what they could do outside in nature, 22 children out of the total of 30 (73%) said that it did, and five of these children (23%) stated that they wanted to do some of the Plum Landing activities again. Three of these children said that they were starting to look at nature differently now that they had watched the videos and done the activities. Only five children stated that Plum Landing did not give them new ideas, and three were unsure if the program helped them think of new things to do outside.

When asked if Plum Landing helped them think of new places to explore, 22 out of 29 children (76%) said yes. Their answers ranged from very small locations, like under rocks or in trees, to larger areas like the park, the forest, and even space (likely inspired by the main character, Plum, being an alien). Only three children said no, while four were unsure if Plum Landing helped them find new places to explore.

¹ We converted responses to ordinal values ("yes" = 2, "depends" = 1, and "no" = 0) and compared children's pre-test and post-test responses using a paired samples t-test. The difference was not statistically significant ($t_{(df=27)} = -0.441, p = .663$).

When asked if Plum Landing helped them feel more or less like learning about science, 23 out of 26 children (88%) who answered this question said that it helped them feel more excited about science. As one child described, “Plum Landing is like a friend and teacher for me. I like the cartoon characters shown in the videos. I feel like I am with them doing those activities.” Only two children said Plum Landing made them feel less like learning about science. Only one was neutral, saying they already liked science a lot, and one was unsure of how Plum Landing affected their excitement about science.

Children’s Content Knowledge

We asked children six content questions designed to assess their knowledge of a set of environmental science constructs addressed in the Plum Landing program. These included questions about animals, plants, seeds, and plant/animal interdependence (for example, “What do animals need to survive and be healthy?” and “How do plants spread their seeds far and wide?”) The children’s answers to these questions were scored and children earned either zero, one, or two points for a possible total content score of between zero and 12. Table 4 explains how the responses were scored.

Table 4
Scoring Children’s Responses to Science Questions

Score	Reasoning and Description
0	Answer is incorrect, child is unsure of answer, and/or child did not respond to question
1	Child on the right track to correct answer, and/or child only answered part of the question
2	Answer is correct

Four children were too shy or distracted at pre-test to complete the science content questions adequately and their data were incomplete, so these data are not included in this analysis. At pre-test, children’s total content scores ranged from zero to 11, with a mean of 5.43. At post-test, children’s total content scores ranged from one to 12, with a mean of 7.82 (Table 5). This was a statistically significant difference between the children’s knowledge scores before and after using Plum Landing. For example, at post-test children were more able to identify at least three wild animals that lived near them (e.g., squirrels, wild dogs, birds) versus at pre-test when many could only identify one or two or they included imaginary animals (e.g., unicorns). One question where children demonstrated growth was about how plants spread their seeds. At pre-test, most children responded, “I don’t know.” By post-test, they included responses such as “Bees help to spread them.” Or “Birds help to drop them.”

Table 5
Children’s Content Knowledge Scores Before and After Plum Landing (n = 28)

Pre-Test Average (sd)	Post-Test Average (sd)	Statistically Significant Difference?
5.43 (2.52)	7.82 (2.54)	$t_{(df = 27)} = -5.892, p = .000$

To further assess content knowledge gains after using Plum Landing, we asked parents “Did you or your child learn anything from the activity that you or your child didn’t know before?” All 32 parents reported that their children learned by watching Plum Landing videos and doing the activities. Many parents mentioned that their children learned science content. Though children had some familiarity with the environmental science topics addressed in

the program, parents reported that their children still were interested and were able to expand their knowledge when doing the activities. Several reported that their children learned about new ways that animals, plants, and people can support one another.

Nine parents said that Plum helped them and their children look at nature a bit differently and made them more observant of the world around them. One parent explained, "My husband's family has a dairy farm. [The children] go down there every day because they never thought of it as nature. We never talked about how the plants help the animals until this activity... It was a good activity for us. We're around nature and animals all the time, but we don't talk about it."

In addition to reporting on their children's learning, thirteen parents said that they also learned something from the videos and activities themselves. One parent said, "I didn't know about the way bees communicate. So that was new." Another parent adding onto this by saying, "I'm doing a lot more Googling and researching than I ever did before."

Family Behaviors

At pre-test and post-test, parents reported how much time their families generally spent together outdoors exploring nature (see Table 6). Data collection took place at the start of the COVID-19 pandemic, so the responses may not reflect typical family behaviors prior to the stay-at-home orders but this is the best information that could be gathered. At pre-test, most parents either reported their families spent less than four hours exploring nature together per week (41%) or more than six hours weekly (53%). By post-test, 88% reported spending more than four hours together exploring nature on a weekly basis. We asked parents whether this was less, the same, or more time than prior to the Plum Landing study and 14 parents (44%) reported that they were spending more time together as a family exploring nature than before the study began. The remainder reported that they were spending the same amount of time as before. The number of hours reported by parents was statistically higher after using Plum Landing. We converted responses to ordinal values ("less than 2 hrs" = 1, "2-4 hrs" = 2, "4-6 hrs" = 3, and "more than 6 hrs" = 4) and compared pre-test and post-test responses using a paired samples t-test. The difference was statistically significant ($t_{(df=29)} = -2.443, p = .021$).

Table 6
Families' Weekly Nature Exploration in Hours Before and After Plum Landing

Total Time per Week	Pre-Test Count (%)	Post-Test Count (%)
Less than 2 hours per week	3 (9.4%)	1 (3.1%)
2-4 hours per week	10 (31.3%)	3 (9.4%)
4-6 hours per week	0 (0.0%)	8 (25.0%)
More than 6 hours per week	17 (53.1%)	20 (62.5%)
Unknown	2 (6.3%)	0 (0.0%)

At post-test, we asked children, "Did Plum Landing make you feel more or less like spending time outdoors exploring nature?" Twenty-one out of 32 children (66%) reported that Plum made them want to spend more time outside. Many stated that they began to notice new things about nature and enjoyed learning new things while going outside. Two children were neutral, as they felt they already went outside a lot. One child said, "I play outside plenty, but if people don't play outside a lot [Plum Landing] would be good to encourage them to." Five children did not think that Plum made them want to go outside more. Three were unsure of how Plum made them feel about going outside.

We also asked parents "Do you think your experience with Plum Landing will change the kinds of outdoor activities your family will do in the future?" Twenty out of 24 parents (83%) reported that they believed their experience will change what activities their families will do. One parent explained, "I think the template of watching videos indoors and then learning about it more outdoors, I think it's a good combination... We might do more of that." The parents who said yes described how they liked that Plum had influenced their children's curiosity and excitement about learning with minimal tools and special materials necessary. One parent said, "After looking at the parent videos and then seeing honestly how simple the activities were, before reading all that stuff I thought it was going to take a lot more planning to do. But I realized as far as the material, it's stuff that we really already had in the house." Another parent added onto this by saying, "I realized that it's not that hard to include science. So I thought this would be so much fun. We've never collected rocks before. So I thought, 'Well, maybe I can take them to like a different park and see what rocks they can find there.' Yeah. So yeah, it just seemed like science. A lot of those things are free... It's just knowing what to do."

Most of the parents (30 out of 32 or 94%) had a very positive response to Plum Landing and plan to use what they experienced while trying Plum Landing to change how they talk about science and nature with their children. Two parents said that Plum Landing will not change the activities they do with their children. Two parents were unsure if the program would change the kinds of activities they would do with their children.

In addition, we asked parents "One of the goals of Plum Landing is to encourage children to be physically active while investigating the outdoors. Did you feel that Plum Landing helped your child be physically active? Please explain." Twenty-three out of 28 parents (82%) said that Plum Landing helped their children be more active outdoors. One parent described how they used Plum Landing to encourage their child to be excited about going outside, saying, "It's hard to get her to go outside and run around when she can't play with other children because of everything going on. So this was the incentive. Hey, we need to go tell Plum." One parent suggested turning the Plum Landing activities into a club, explaining, "These kinds of platforms are really helpful to gain knowledge and...proving the mental ability to think differently and question sessions, we can arrange with multiple children. If it is arranged by a club... then it, it can be helpful if children participate [with] their parents and ask questions [to] each other."

Evaluation of Plum Landing

When asked to describe their overall experience with Plum Landing, all but one parent (31 out of 32 or 97%) reported that they enjoyed Plum Landing. One parent was neutral about their experience. We asked parents whether they would recommend Plum Landing to other families. All parents (100%) reported that they would recommend it.

We asked parents whether they planned to continue using Plum Landing. Nearly all (97%) reported that they "might" or "definitely" would continue using Plum Landing.

We asked parents to rate how easy or difficult it was to integrate Plum Landing into their everyday lives on a scale of 1 (Extremely difficult) to 5 (Extremely easy). The average rating parents gave Plum Landing was 4.25 (sd = 0.76), thus, on average parents found it very easy to integrate Plum Landing into their everyday lives. Two parents reported that, while Plum Landing was easy to integrate, the pandemic made it more challenging for them, given how much screen time their children were getting with virtual school or the stress of social distancing.

Discussion

The research and development team's central conjecture in researching, developing, and assessing the Plum Landing Explore Outdoors Toolkit was that active, outdoor nature exploration can increase children's environmental science habits of mind (i.e., questions you need to ask when investigating an ecosystem) and content knowledge, and can have an impact the kinds of activities that families do together, ultimately leading to an enhanced sense of connectedness with nature. In this section, we'll first discuss the evidence of success in achieving these outcomes, and then we'll consider the factors that may have contributed to successes and challenges.

Evidence of Success

This study provided evidence that use of the Plum Landing Explore Outdoors Toolkit led to increases in children's environmental science **habits of mind**, particularly around curiosity about nature and the desire to share new information and ideas about nature. Children also increased their **environmental science content knowledge** as a result of using Plum Landing, scoring higher on average from pre to post on a set of constructs that address ideas related to animals, plants, seeds, and plant/animal interdependence. In addition, all parents (100%) reported that their children learned at least a little bit by using the Plum Landing resources. Though some children already had familiarity with the topics, parents reported that their children were still interested and were able to expand their knowledge.

Families also changed their **behavior in nature** as a result of using Plum Landing: the amount of time they spent outdoors together exploring nature was significantly higher from pre to post, and most parents reported that Plum Landing helped their children be more active outdoors. In addition, a majority of participating parents said that they believe the experience will have an impact on the kinds of activities they do outdoors together in the future. Children expressed similar thoughts: when asked if Plum Landing influenced their ideas of what they could do outside in nature, 22 out of 26 children (85%) said that it did. Children reported that Plum Landing helped them think of new places to explore, from very small locations, like under rocks or in trees, to larger areas parks and forests.

Factors Leading to Success

To better understand families' context and motivation for using Plum Landing, researchers at CEG analyzed families' responses to open-ended questions about their opinions on the materials, successes and challenges in using them, and how they differ from other resources used by families. Their answers provided a clearer understanding about how different elements of Plum Landing contributed to families' use of the materials and supported their engagement in outdoor nature exploration. This information complemented previous iterative research on the Toolkit that had been conducted with educators and children in informal learning settings, such as afterschool programs and education programs based at nature centers.

Active, outdoor science exploration can be done close to home and doesn't need special tools or equipment. All families were able to engage with the Plum Landing materials, even while living under the restrictions of the current health pandemic. For some, this meant a full lockdown for the duration of the study; for other families, it meant alternating periods of imposing and lifting of restrictions. Families did articulate some obstacles, such as fears about safety or challenges coping with the stress of social distancing. However, all families, regardless of where they were living, were able to use the materials to explore nature. One parent commented, "The app and the activities are great and easy to follow. Good activities for children around my son's age to get engaged in even with little supervision." Another said, "The activities required minimum supplies. We were able to make it family fun and it never seemed like 'work.'"

Parents appreciate materials that provide structure and guidance for exploring nature. Parents felt comfortable overall in their ability to lead outdoor science activities, but appreciated elements of Plum Landing that enhanced their ability to do so. All of the parent reported that they checked out the videos and printable "tips" for parents, which were designed to support parents in exploring science outdoors. In addition, in response to open-ended questions about the Toolkit, several parents said they liked how the Plum Landing materials provided ideas and

guided instructions for exploring nature and having fun outside. One parent commented on how the directions that outlined the learning goal for each activity enhanced its educational value. “It kind of gave the activity a purpose because a lot of the times we're doing things that it seems like they're not really learning... It kind of guides me or it's like a segue between fun and learning.”

Parents value materials that are easy to integrate into families' everyday lives. In talking about what they liked and didn't like about Plum Landing, several parents said that it offered new ways to teach their children about nature or added more to what they were already doing with their children. For example, one parent reported that Plum Landing “gave us new activities to do with our daily outside time.” Another said, “the videos and activities gave us talking points on our daily walks. The children notice things in nature that they didn't notice before, which initiated great conversations.”

Parents liked that the materials supported the participation of the entire family. The vast majority of the materials—including the videos, activities, badging feature, and online game—were explored by both the parent and child together. One parent specifically mentioned that they liked how Plum Landing got the entire family involved in the lessons it teaches, encouraging parents and siblings to do activities together. Other parents also mentioned using it with siblings. One reported, “We went out and did the corresponding activities... sometimes just the two of us and sometimes with other siblings.”

Parents appreciated that the materials reflected their own values for their children. In addition to meeting their expectations for teaching about nature, parents also appreciated that Plum Landing met their other priorities and values that they hold for their children. Several parents said that Plum Landing worked well with how their children learned and how their families preferred to have their children learn, saying that they felt that Plum Landing (and PBS) felt age-appropriate, easy to use, and safe for their children to explore on their own. One parent added onto this by explaining how they appreciated the diversity of the characters, saying that Plum Landing “seems to be a diverse platform for each and everyone.”

The characters and media were motivating for children. When asked what they liked and didn't like about Plum Landing, many of the children reported having positive experiences with Plum Landing. Several children who responded said they really enjoyed the videos, many saying they liked the characters and the concepts taught in each episode. For example, one child reported, “Plum Landing is like a friend and teacher for me. I like the cartoon characters shown in the videos. I feel like I am with them doing those activities.” Parents agreed that the videos were motivating for the children. One reported, “The video was short, to the point, and interesting. [My child] watched the videos and was interested in the information.”

Parents appreciated the affordances offered by technology. While previous research suggested that some educator-led nature programs pride themselves on not using technology, and prefer to keep it that way, families in this study were very receptive to the idea of using technology to motivate and enhance nature exploration. Parents used the materials in different ways (printing activities vs accessing on devices, watching videos indoors or outdoors, watching together vs separately) and seemed to appreciate that different resources offered different ways to engage. A couple of parents mentioned being mindful about screen time, but were still able to adapt how they used the resources to complete the study.

Study Limitations

This study had several limitations. First, the sample size was small and did not allow for more inferential statistics to be used. Second, the families that self-selected to be a part of the study may have been more motivated to engage in the program simply because they were more interested than the general public in research, generally, or in environmental science in particular. Third, the lack of a control or comparison group means that we aren't able to know what families might do in the absence of the program and whether changes we observed in children's behaviors, for example, are due to the program itself or some external factor.

Areas for Further Research

This evaluation study provided evidence that digital media could be used effectively to encourage children and their families to explore nature together. The findings also raised some additional research questions that are worth exploring. For instance, it would be informative to know whether these findings could be replicated with a sample of children who do not hold such positive attitudes about nature and the environment as the children in the sample. Also, it would be useful to explore whether digital media can be used equally as effectively by families in much more rural locations than the ones targeted by this project. Finally, it would be interesting to follow-up with the families in the study to assess the extent to which they actually continued using Plum Landing and the factors that contribute to long-term use or non-use and whether families' interest in nature exploration persists long-term after using a digital media program like Plum Landing.

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