



EXTERNAL EVALUATION REPORT

For LINEAGE: A Cross-Platform
Learning Experience Exploring the
History of Life on Earth

2021



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INTRODUCTION

“LINEAGE: A Cross-Platform Learning Experience Exploring the History of Life on Earth” project, or “Lineage” for short, was a project funded by the National Science Foundation. It was a collaboration between Twin Cities Public Television (TPT) and the Smithsonian’s National Museum of Natural History (NMNH). The project included creation of a feature-length **video program**, a Virtual Reality game, and a set of **hands-on activities** –all of which were incorporated as part of a series of seven Fossil Festival events at museums and other sites around the United States.

When Whales Walked Video



Deep Time Detectives VR Game



Fossil Festival Events

(featuring the video, the VR game and a series of hands-on activities)



OVERVIEW OF EVALUATION

Rockman et al (REA) served as the evaluation partner for the project. The evaluation effort included a front-end study that explored parents’ understanding of evolution and big history, interest in STEM and specific evolutionary topics, and experiences and beliefs related to family co-learning experiences. During the formative stage, the external evaluation gathered feedback on early iterations of the *When Whales Walked* video program at key points during its development process. Focus groups were also convened to assess adults’ understanding of concepts related to evolution and attitudes toward family co-learning and VR-based educational experiences.

Then, during the summative evaluation stage, the external evaluation team examined the breadth and depth of programmatic impacts on families who participated in Fossil Festival events at various sites around the United States. Evaluation at this stage included comparisons within and between sites and an evaluative study on the impact of video viewership on resulting VR and hands-on experiences.

Additionally, during the summative evaluation stage, the external evaluation team considered the outcomes and impacts of the project on ISE professionals, e.g., improved skills in designing and/or facilitating family co-play experiences. This report focuses primarily on findings from the summative evaluation stage, as previous reports covered findings from earlier stages of the evaluation.

EVALUATION GOALS & QUESTIONS

In the summative stage, the evaluation focused on three key objectives: 1) learning about the impacts of the Fossil Festivals, 2) learning about the impact of video on families' co-play experiences and the program's ability to help parents grasp and explain challenging or abstract concepts to children, and 3) learning about programmatic impacts on ISE professionals who were engaged in the Lineage project in various ways. Evaluation questions related to these overarching objectives were as follows:

- a) whether the Fossil Festival experiences increased participants' **understanding** of specific topics and STEM in general,
- b) whether participants felt more **comfortable** with STEM,
- c) whether participants came to be more **interested** in STEM and other STEM learning opportunities,
- d) whether **parents** came to feel more **empowered** to support their children's learning,
- e) whether participants came to feel more **empowered** to learn together **as family units**,
- f) whether participants came to be more **aware** of the role that STEM plays in their life, and,
- g) whether, and to what extent, the program had an impact on **ISE professionals**.



METHODOLOGY

Methods for studying Fossil Festival impacts and outcomes

Members of the evaluation team attended each of the six regional Fossil Festivals (two each in **Nebraska**, **New Mexico**, and **Tennessee**) as well as a Fossil Festival event at the Smithsonian’s National Museum of Natural History in **Washington, D.C.**. While on-site for each of these events, evaluators conducted observations of participants engaging in Fossil Festival activities—including observations of engagement with the four hands-on activities that were designed by staff members at the Smithsonian’s National Museum of Natural History (NMNH) and use the VR game, *Deep Time Detectives*, designed by Schell Games in collaboration with staff members from NMNH as part of the Lineage project. Survey data were also collected, with help from staff and volunteers at each site, and a sample of participants were interviewed.

Figure 1: Fossil Festival Locations



Methods for studying the impact of video on families' co-play experiences

The evaluation team sought to explore the impacts of the *When Whales Walked* video programming on resulting family co-learning experiences. To that end, two evaluative studies were designed and implemented as part of the Fossil Festival events.

The first study was designed to determine whether or not viewing a part of the *When Whales Walked* video program beforehand had an impact on resulting *Deep Time Detectives* VR game-play experiences. Data for this study were gathered at each of the six regional Fossil Festivals (in Nebraska, New Mexico and Tennessee). Two parent-child dyads were invited to participate in each session. One group watched the whale segment of the video program first and then played the game, while the other group played the game first and then watched the whale segment of the video program. Families were interviewed after they completed the game.

The second evaluative study was conducted at NMNH and was designed to examine whether viewing just the whale segment of the video in comparison to viewing the full *When Whales Walked* program had discernible impacts on families' co-learning experiences for either the hands-on whale activity or the *Deep Time Detectives* VR game. Evaluative analyses for both studies included identification of trends and testing of emerging hypotheses within qualitative data as well as statistical analysis of available quantitative data.

Table 1: Overview of Data Collected at Fossil Festivals

	Washington D.C. Event	Nebraska Events	New Mexico Events	Tennessee Events
Participant Surveys	✓	✓	✓	✓
Participant Observations	✓	✓	✓	✓
Participant Interviews	✓	✓	✓	✓
Video vs. No-Video Study		✓	✓	✓
Full vs. Short Video Program Study	✓			

Methods for studying the impact of the Lineage Project on ISE Professionals

Members of the evaluation team observed a training session held in Washington, D.C. for ISE professionals who were selected to help facilitate the regional Fossil Festivals. Feedback was then gathered from site facilitators and volunteers via a mix of interviews and focus groups immediately following the Fossil Festival events and approximately one year after the final Fossil Festival event. In the summer of 2021, members of the evaluation team also observed an online workshop for ISE professionals. Each round of evaluation that involved ISE professionals explored whether (and to what extent) the project provided a functional and effective model for enhancing each outreach site's family-learning abilities and capacity and how the participating science centers and rural outreach partners feel about their involvement.

CHAPTER 1: FOSSIL FESTIVAL FINDINGS

In this chapter, we present a summary of findings related to outcomes of the Fossil Festival events. These findings are the combined result of participant surveys, participant observations, and participant interviews.

OVERVIEW OF EVENTS

Fossil Festival events were designed to be similar in many key ways—including screenings of the *When Whales Walked* video program, opportunities for participants to do the *Deep Time Detectives* VR experience, and inclusion of three of the Smithsonian-designed hands-on activities. However, each site added their own unique “flair” to their event by including additional activities, original presentations, and locally-relevant partners. For example, in New Mexico, facilitators chose to call their events “Fossil Fiestas” as a tie-in to local culture. They also commissioned an original play featuring puppets and a character called “Indiana Bones” and featured a Paleoartist who was a big hit with youth participants. The event at the Farmington Public Library also featured a selection of relevant books about fossils and paleontology. Presenters and exhibitors at other events shared information about nearby fossil-related sites of interest, and STEM careers. The event at the Ashfall Fossil Beds State Historical Park in Royal, NE highlighted the active fossil dig site and fossil preparation laboratory at their site. Fossil Festival events also incorporated a variety of unique crafts.

Of particular interest to the evaluation effort were participants’ opportunities to play the *Deep Time Detectives* VR game, watch the *When Whales Walked* video and/or participate in a selection of three out of the four hands-on activities developed by the team of collaborators at NMNH—including:

- *Marine Revolution*: An activity related to the VR game and whale segment of the *When Whales Walked* video program wherein participants explore evidence and use the phylogenetic tree to discover that animals that look similar are not always the most closely related.
- *Elephant Evolution*: An activity that studies relationships between several elephant ancestors using replicas of their teeth.
- *Dinosaurs Take Flight*: An activity that leads participants through the process of discovering when dinosaurs developed the ability to fly.
- *Tiny Fossils, Big Picture*: An activity about Fossil Pollen and how environmental features can influence the evolution of creatures living in a location.

The following table provides a summary of the activities that were included at each Fossil Festival.

Table 2: Hands-on Activities Featured at Each Fossil Festival

	DC (NMNH)	Lincoln, NE	Royal, NE	Albuquerque, NM	Farmington, NM	Knoxville, TN (McClung)	Knoxville, TN (Norwood)
Whale	✓	✓	✓	✓	✓	✓	✓
Birds				✓	✓		
Elephant	✓		✓	✓	✓	✓	✓
Fossil Pollen	✓		✓			✓	✓

FOSSIL FESTIVAL EVENTS IN PHOTOS

Fossil Fiesta

Schedule of Events		
Family Fossil Activities	9am – 4pm	Atrium
Meet a Paleontologist	9am – 4pm	Atrium
Meet a Paleoartist	9am – 4pm	Atrium
FILM: When Whales Walked	9am – 4pm	STEM Theater
Virtual Reality Experience (schedule your time at the door)	10:12:30-2:00am	Classroom #2 Highlands Classroom
Story Time	10am, 11am, 12pm	Classroom #1
Early Childhood activities	10:30am, 11:30am, 12:30pm	Classroom #1
Indiana Bones, Story Teller	2pm, and 3pm	Atrium
Flight Evolution activity	9am – 1pm	Jurassic Hall
Whale Evolution activity	9am – 1pm	Cretaceous Hall
Elephant Evolution activity	9am – 1pm	Ice Age Hall

New Mexico Museum of Natural History & Science



**FESTIVAL DE FÓSILES
NORWOOD ELEMENTARY**

**SÁBADO 2 DE NOVIEMBRE
12:30 - 4:30 p.m.**



- Juegos educativos
- Exploración científica con profesionales
- Actividades en familia

¡Evento familiar gratuito!

McCLUNG MUSEUM of Earth, History and Culture

Photo credits for preceding page: Row One: a schedule for the Fossil “Fiesta” event in Albuquerque, NM; a family participating in the Elephant Activity at the Fossil Festival in D.C., **Row Two:** families participating in the Elephant Activity in Lincoln, NE; Participants completing the first part the Elephant Activity at Norwood Elementary for the first of two Fossil Festival events held in Knoxville, TN; and participants at Norwood Elementary playing *Deep Time Detectives* at Norwood Elementary. **Row Three:** Participants at the Fossil Festival in Lincoln, NE; a view of attendees at the Fossil Festival in D.C.; families viewing the “Indiana Bones” puppet show in Albuquerque, NM. **Row Four:** participants completing the Bird Activity at the Farmington Fossil Fiesta; a participant completing the Fossil Pollen activity in Royal, NE; and a flyer promoting the Fossil Festival Event in Knoxville to Spanish-speaking families. All photos were taken in accordance with local event/institutional guidelines, by a member of the REA evaluation team.

PARTICIPANTS

Across all sites, there were several hundred Fossil Festival participants. In order to maximize opportunities to observe and interview participants, the evaluator attending each event coordinated with site volunteers to help collect participant survey data. Some sites offered small incentives (e.g., stickers) for completing the survey, whereas others did not. Survey response-rates therefore varied greatly from site to site and were not ultimately conducive to most statistical analyses, but did, however, help to reveal some trends. The number of surveys collected, participants observed, and participants interviewed at each Fossil Festival event are summarized in the table below.

Table 3: Evaluation Participant Numbers Across Fossil Festival Sites

	Washington D.C. Event	Nebraska Events	New Mexico Events	Tennessee Events
Participant Surveys	198 <small>(including a mix of the Evaluation survey and NMNH survey)</small>	Lincoln: 16 Royal: 3	Albuquerque: 136 Farmington: 70	McClung: 13 Norwood: 21
Participant Observations	25	Lincoln: 11 Royal: 3	Albuquerque: 5 Farmington: 11	McClung: 6 Norwood: 10
Participant Interviews	25	Lincoln: 11 Royal: 3	Albuquerque: 7 Farmington: 9	McClung: 6 Norwood: 10

PARTICIPANT ENJOYMENT & INTEREST IN STEM

Across all events there were indicators that participants enjoyed the Fossil Festival Experiences. On a scale from 1-5 (1 = “Not at all” to 5 = “A lot”), the average response to the question “How much did your family enjoy this event?” across all events was 4.60. There is also evidence from observations and interviews with participants to corroborate the fact that participants enjoyed the Fossil Festivals, and that enjoyment, in turn, fostered increased interest in STEM—though the later was harder to quantify.

PARTICIPANT UNDERSTANDING & COMFORT WITH STEM CONCEPTS

The evaluation also sought to gather input from participants on whether the Fossil Festival experiences had increased their understanding of specific topics and/or STEM in general. On a scale from 1-5 (1 = “Nothing at all” to 5 = “A lot”), the average response to the question “How much did your family learn at this event?”

across all events was 4.44. In addition to more general comments (e.g., “I learned a lot today” or “Kids had so much fun and learned a lot and connected to items they are learning in school”), the following comments are examples of the types of specific things participants said that they learned—including things they learned about the scientific processes involved in studying connections between ancient creatures and those living today, as well as facts about particular animals.

Quotes that illustrate what participants learned about the processes involved in studying the connections between ancient creatures and those living today:

- [We learned] “more about whales and the paleontology process” (Albuquerque Fossil Festival participant)
- “Process of looking at skulls to find relationships” (Farmington Fossil Festival participant)
- “Just because animals don't look exactly the same doesn't mean they aren't closely related” (Lincoln Fossil Festival participant)

Quotes about facts related to evolution and specific animals:

- “Ancestors of whales walked on land” (Albuquerque Fossil Festival participant)
- “Whales and deers are related” (Norwood Fossil Festival participant)
- “Pigeons are basically dinosaurs” (Farmington Fossil Festival participant)
- “Dinos are original birds” (Albuquerque Fossil Festival participant)
- “Elephant/mammoth teeth slide in from back” (McClung Fossil Festival participant)
- “Mastadon’s lived in Tennessee!” (Norwood Fossil Festival participant)
- “All vertebrates have tongues” (Albuquerque Fossil Festival participant)
- “That the environment can change a lot over time” (Lincoln Fossil Festival participant)
- Dinosaur era trees didn’t have bark! (DC Fossil Festival participant)

It is interesting, but perhaps not surprising, to note from the comments above that many of the things that participants learned were related to the specific hands-on activities offered at each site. It is also worth noting that many of the youth attendees at the Fossil Festival events were below the target age-range for the hands-on activities developed by the Smithsonian. Younger participants tended to only get through part of the hands-on activities, but partial completion seemed to be sufficient to foster engagement and promote scientific thought and activity. Facilitators at each event came up with ways to shorten or simplify activities so that even the youngest participants were coming away with greater understanding of some basic STEM processes and concepts that relate to evolution.

LEARNING TOGETHER

Through observations of participant engagement with hands-on activities at the Fossil Festival events, our team members noted that parents/caregivers often defaulted to allowing children to do the activities on their own—looking on from a distance, attending to other children, and/or talking with other parents while groups of children participated. However, we also saw instances of facilitators inviting parents/caregivers to participate in activities together with their children. Some site facilitators also noted that they had made

efforts to encourage more parent engagement. Subsequently, many site facilitators said they saw greater engagement among family units than typically seen at educational programs or outreach events.

When adults did participate in the activities alongside children, it was typical to see them prioritizing children's ability to participate, e.g., allowing children to answer questions and form hypotheses, and take the lead on collection and analysis of data for the activity. We also noted instances where youth were particularly proud or excited when an answer they'd given or advocated for was correct. Similarly, youth were also pleased when they knew something that the adult doing the activity with them did not know—this was frequently the case when it came to facts about dinosaurs.

Additional insights on family co-learning were gained from the somewhat more structured evaluative study about the impacts of viewing either the full or shorter version of the *When Whales Walked* video on subsequent VR and hands-on experiences. Those findings will be presented in the next chapter of this report.

PARTICIPANT AWARENESS OF STEM'S IMPACTS

When it comes to impacts on participants' awareness of the role that STEM plays in their lives, the activity that seemed to have the greatest impact was *Tiny Fossils; Big Picture*—the hands-on activity about fossil pollen and how scientists use fossilized pollen to learn more about environmental changes over time. Participants completing this activity noted things like the presence and absence of certain types of trees and plants and easily surmised the likely impacts on creatures living in environments with different trees and plants to eat. From there, participants were quick to realize the impacts that current environmental changes—especially those due to climate change—may have on creatures living today in different environments. As a result of this activity, many participants successfully made the connection that environmental changes could impact humans in the not-so-distant future.

OTHER FINDINGS

Observations and interviews with Fossil Festival participants suggest that the involvement of trained facilitators makes the hands-on activities more engaging. Participants found it particularly engaging when they had opportunities to interact with real scientists. In other instances, participants noted the value of being able to do an activity that was led by someone they identified with, e.g., a youth-volunteer or a facilitator who shared cultural or ethnic characteristics in common with participants. The latter was especially important for participants for whom English is not the primary language spoken in their household. Many of the Fossil Festival events had facilitators who were able to conduct the hands-on activities in Spanish or other languages spoken by participants—including a Native American facilitator in Farmington who not only helped to translate activities into the Navajo language spoken by some local attendees, but was also able to address cultural taboos related to touching bones and fossils.

CHAPTER 2: VIDEO STUDIES FINDINGS

As part of the evaluation effort for the Lineage project, the evaluation team sought to examine the impacts of video viewing on subsequent co-learning experiences. The first evaluative study was designed to compare outcomes for a group of parent-child dyads who viewed a short clip from from the *When Whales Walked* program and then completed the *Deep Time Detectives* VR experience in contrast to those who engaged in the VR activity *before* watching the video.

The second evaluative study sought to examine the impacts of viewing a short version of the *When Whales Walked* video program—featuring only the segment about whales—in contrast to viewing the full program. Specifically, this study looked for similarities and differences in subsequent co-learning experiences and outcomes resulting from either the *Deep Time Detectives* VR experience or the *Marine Revolutions* hands-on activity.

ABOUT THE *WHEN WHALES WALKED* VIDEOS

Produced by Twin Cities Public Television, the *When Whales Walked* video program features segments about the deep-time history and evolution of four types of creatures, including whales, birds, elephants and crocodiles. The video has a diverse array of scientists and provides insights into how they do research and what they have come to know about the evolution of the aforementioned creatures. The program also features immersive visuals that help viewers to envision ancient ancestors of these majestic creatures. The **full video program** runs just under two-hours, whereas a **shorter version**, lasting approximately thirty minutes, was developed to support the research and evaluation efforts for the Lineage project. The later focuses primarily on whales and the whale ancestor, Pakicetus.

ABOUT THE *DEEP TIME DETECTIVES* VR EXPERIENCE

Created by Schell Games, *Deep Time Detectives* is a two-player cooperative experience. One player wears a VR headset and takes on the role of “field paleontologist.” The second player uses supportive information and resources provided on a separate video monitor to help identify a fossil that is uncovered by the field paleontologist. Working together, players come to learn that the fossil is a Pakicetus—an ancient whale ancestor that once walked on land.



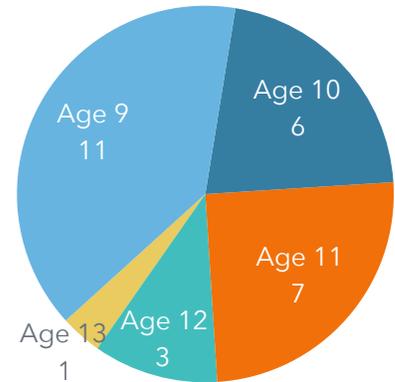
EVALUATIVE STUDY ONE:

EFFECTS OF VIDEO VIEWING ON RESULTING VR EXPERIENCE

Participants

Rockman staff observed thirty-four pairs of participants across the six participating sites—including six families at five sites and four families at the sixth site. Participating children ranged from 8 years-old to 13 years-old (see Figure to the right), and there were twice as many boys (n=24) than girls (n=12). Most of the pairs included an adult and a child. In each of those instances, the child was always the one who chose to wear the VR headset. In two instances, however, the observed pairs were formed by two children with a parent observing and providing periodic support. Only a few of the participants noted that they had had previous experiences with VR.

Figure 2: Participants' Ages



Methods

Participants were either shown the video clip first and *then* invited to do the VR experience (or vice versa). Rather than being evenly split across the two conditions (video-first vs. VR-first), twenty families viewed the video before doing the VR experience, whereas fourteen did the VR experience first. In some cases, this was the result of it taking more time than anticipated to get the VR system set up for participants, and in other cases, it was a factor of participants running late for scheduled sessions. A standardized set of interview questions were asked after participants completed the VR experience. The interviews were audio-recorded and later analyzed using emergent coding to identify patterns across sites.

Data from thirty-one of the VR play sessions were determined to be at least partially code-able. Videos of VR experiences were divided into five sections, including an introductory segment that leads up to the first decision-point, three additional "decision points", and a closing scene wherein participants could explore the 3D world. The sections were as follows:

- **Section 1:** From the beginning of VR experience to **Decision Point 1** - Generating an initial hypothesis about whether the fossil is a relative of a modern day seal, dog, whale, or deer.
- **Section 2: Decision Point 2A** - Comparing the Pakicetus ankle bone and, if players hadn't already selected "deer," **Decision Point 2B** - Updating the hypothesis.
- **Section 3: Decision Point 3** - Comparing the Pakicetus jawbone.
- **Section 4: Decision Point 4** - Scanning for bone density & confirming the hypothesis.
- **Section 5:** At the end of the game players had an opportunity to **explore the environment** and see/interact with a virtual Pakicetus.

Figure 3: Overview of Key Decision Points within *Deep Time Detectives*



Each section was coded for the presence of six elements we expected to see in a cooperative play/learning experience:

- Sharing directions/game mechanics
- Explanations or descriptions beyond on-screen text
- Open-ended questions
- Closed-ended questions
- Reference to film/hands-on activity
- Reference to other personal experiences

In addition to noting the decisions participants made, evaluators also sought to determine who was guiding decision-making in each section of the VR experience. Findings related to each section and relevant decision points are presented below.

Findings

Section 1: Beginning of game to first hypothesis

At the beginning of the VR experience, participants had to unlock the dig site. To do so, the out-of-VR player verbally shared a passcode with the player wearing the VR headset. After entering the code, the player wearing the VR headset was then able to use a brush to gently uncover the fossil. Evaluators noted instances where players required more time or assistance to get acclimated to the VR environment and gameplay mechanics. At the end of this section, participants had to form a hypothesis about which modern-day animal the uncovered fossil was related to. Both players had to agree on their selection. The four choices included: Seal, Dog, Whale or Deer.

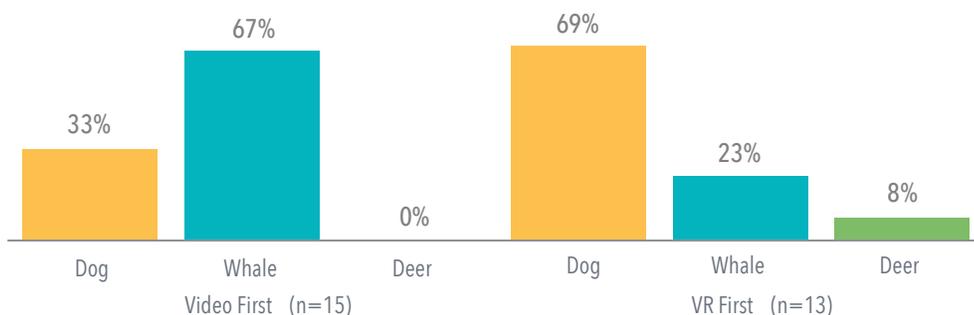
Figure 4: Screen Image Showing Decision Point 1



Note: The image above shows what the player without the VR headset sees during the VR experience—including elements of what is being seen by the partner wearing the VR headset and additional instructions to the right of that image, along with the input options: “Seal,” “Dog,” “Whale,” and “Deer”. The overlaid image in the lower right-hand corner shows what the player wearing the VR headset sees.

Overall, a majority of participants thought the closest living relative of the fossil was a dog; with whale being the next most frequently selected option—a trend that seemed to be strongly influenced by prior viewing of the video. Sixty-four percent of participants who saw the video first hypothesized that the fossil was a whale compared to 33% of participants who played the VR game before seeing the film. Out of thirteen distinct references to the film that were coded during the sessions, 54% happened during this section of the VR experience. It is also worth noting that a few participants who had seen the video first noted that it couldn't possibly be the same type of creature they'd just seen in the video. No participants hypothesized that the fossil was a seal and only one team hypothesized that it was a deer.

Figure 5: Distribution of Participant Choices at Decision Point 1



Section 2: Comparing the Pakicetus Ankle Bone & Refining the Initial Hypothesis

Leading up to the second decision point, participants had to compare the Pakicetus ankle bone to ankle bones representing two fossil groups, i.e., the Whale-Deer group and the Seal-Dog group. These groups represent evolutionary families with common ancestors. The player in VR is prompted to describe the bone to the player who is not wearing the VR headset. The latter player can see the fossil group examples but cannot see the Pakicetus ankle bone, whereas the player wearing the headset can only see the Pakicetus's ankle bone, but cannot see the two fossil group examples. At this point in the VR experience, a facilitator sometimes had to step in to explain that each player was seeing something slightly different on their screen and reminded the players that they had to work together to determine the correct “group” for the bone they had found.

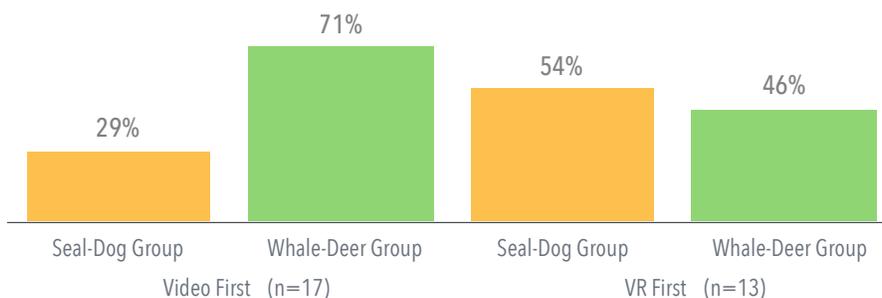
Figure 6: Screen Image Showing Decision Point 2A

Note: The image to the right shows what the player without the VR headset sees during the VR experience. Messaging for that player indicates that only they can see the two bones that are displayed. Red arrows indicate the number of “bumps” on each of the two bones and the text encourages the participant to ask about and emphasize these bumps as a differentiating feature when talking to the partner wearing the VR headset. Below the image is a place for the participant to select “Seal-Dog group” or the “Whale-Deer group.” The overlaid image in the lower right-hand corner shows what the player wearing the VR headset sees—i.e., only the bone needing to be identified and the ability to select the “Seal-Dog group” or the “Whale-Deer group.” Both players must again agree on the choice that they select before proceeding.



Again, the majority of participants selected “Whale-Deer group” (i.e., the correct choice), but those who had viewed the video prior to playing were much more likely to make that selection. Seventy-one percent of participants who viewed the video first selected the “Whale-Deer group,” whereas only 29% selected the “Seal-Dog group.” In contrast to players who did the VR experience before viewing the video—whose responses were more evenly mixed, with 54% selecting the “Seal-Dog group” and 46% selecting the “Whale-Deer group.”

Figure 7: Distribution of Participant Choices at Decision Point 2A



It was not possible to advance past this decision point with an incorrect answer. If the participants guessed the Seal-Dog group, they were told the ankle bones did not match and were prompted to submit a different answer. All participants who chose Seal-Dog switched to Whale-Deer at this point.

Decision Point 2B: Updating the Hypothesis

Participants who had not initially selected “Whale” were presented with an opportunity to update their hypothesis to either Whale or Deer. Fewer participants were exposed to this decision point because it was only presented to participants whose first hypothesis had been “Dog” or “Deer.”

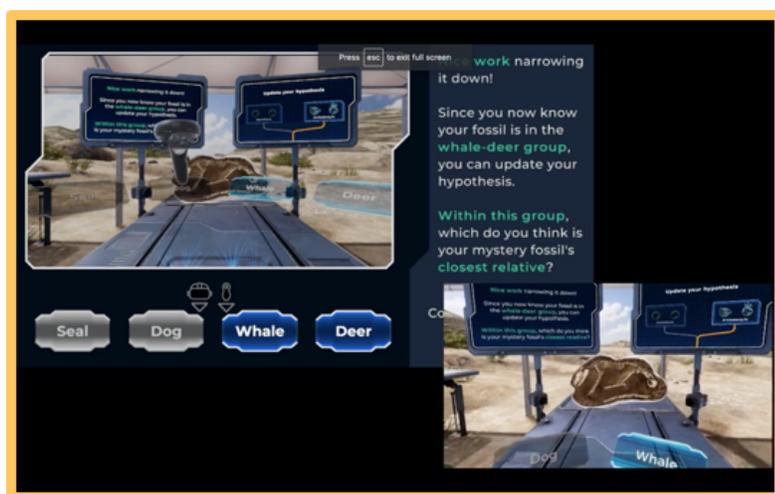


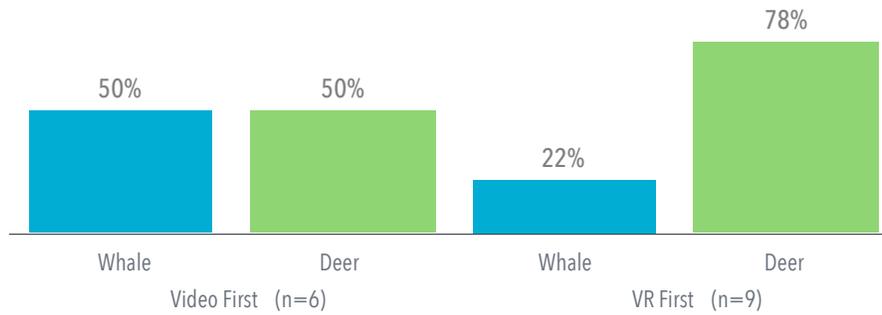
Figure 8: Screen Image Showing Decision Point 2B

The image to the left shows what the player without the VR headset sees at this decision point; the inset image in the lower right-hand corner shows what the player wearing the VR headset sees. Both participants must agree on whether to select “Whale” or “Deer” as their new hypothesis at this stage.

As shown below in Figure 9, 50% of participants who saw the video first updated their hypothesis to “Whale,” (i.e., the correct choice), while only 22% of VR-first participants did so. Those doing the

VR experience before watching the video were more likely to select “Deer” (i.e., 78%). The common rationale for suggesting that the fossil was a deer were the shape of the skull, the presence of “legs,” and its teeth. Several participants stated that whales did not have teeth when making this decision.

Figure 9: Distribution of Participant Choices at Decision Point 2B



Section 3: Comparing the Packicetus Jawbone

At the beginning of this section the player wearing the VR headset had to get the Pakicetus’ jawbone and place it in the designated space. The player not wearing the VR headset had access to jawbones that were representative of the Whale Group and the Deer Group. As was the case with Decision Point 2A, participants needed to collaborate and share information about what they were seeing to determine whether the Pakicetus’ jawbone was more similar to that of the Whale Group or the Deer Group. On screen text encourages the player not wearing the VR headset to ask their partner to describe the fossil they see and to focus on the shape of the teeth and jaw.

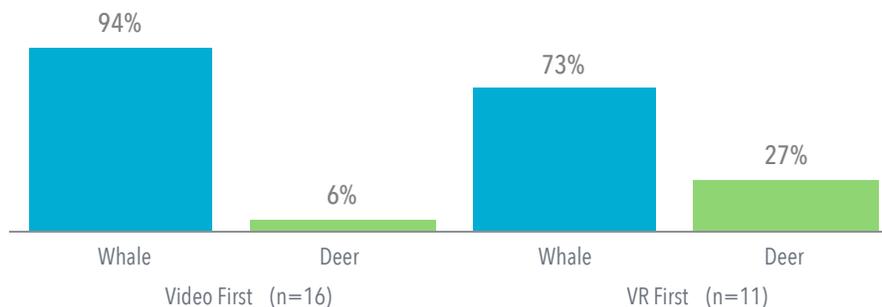
Figure 10: Screen Image Showing Decision Point 3

The image to the right shows what is seen by the player not wearing the VR headset at Decision Point 3. The inset in the lower-right hand corner shows what is seen by the player wearing the VR headset.

At this point, there were only four teams that did not select “Whale,” including only one group who had seen the video before doing the VR experience.



Figure 11: Distribution of Participant Choices at Decision Point 3



Before proceeding to the next section, the teams of players who had selected “Deer” at Decision Point 2B (i.e., the team’s hypothesis about the closest living relative of the fossil they had found, based on the evidence they had seen thus far) were asked to update their hypothesis in light of newly seen evidence. “Whale” was the only choice players were given.

Section 4: Scanning for Bone Density & Confirming the Hypothesis

In the fourth section of the VR experience, players arrived at the final decision point. Here, players were tasked with determining if the ear bone density was more similar to the ear bone density of whales or typical bones. The player not wearing the VR headset was given information on average bone density measurements for whale’s ear bones (~3000 HU) and typical bones (~1700 HU). The player in VR was asked to retrieve the fossil’s skull and use a bone density scanner to determine the density of the fossil’s ear bone and share that info with their partner. The reading of 3026 HU indicates that the density of the fossil’s ear bone is most similar to the density of a whale’s ear bone. Participants were given the choice of confirming their most recent hypothesis (i.e., that the fossil is most closely related to a whale), or asking to review all data if they were still unsure. At this point, 100% of the participants chose to confirm their most recent hypothesis.



Figure 12: Screen Image Showing Decision Point 4

As described above, the figure to the left shows what is seen by the player not wearing the VR headset (i.e., including a window that shows what the player with the VR headset is seeing, information about the average density of a whale’s ear bone, and buttons that ask if they want to confirm their hypothesis or review all data.) The image inset in the lower right-hand corner shows what the player wearing the VR headset sees at this point in the VR experience.

Section 5: Exploring the World

After confirming that the fossil is an ancient whale, participants learn that it is actually a *Pakicetus*, an ancient precursor of modern-day whales. They are then taken to an immersive recreation of ancient Pakistan, rendered in 3D for the player wearing the VR headset (see Figure 13). The player wearing the headset is also able to interact with a virtual *Pakicetus* by moving their hand-held control device around before the creature returns to the water.



Figure 13: Screen Image Showing the Final Scene of the VR Experience

Other Interaction Trends Observed During the VR Experience

As part of the video analysis, sections of the VR experience were coded for occurrences of the following aspects of collaborative play and learning: sharing information, asking open and close-ended questions, providing explanations beyond on-screen text, and making reference to other experiences. The following is a synopsis of what was learned through analysis of video footage collected as part of the first evaluative study.

Sharing Information

All of the decision points within the VR experience involved players sharing information with each other that their partner typically could not see. For example, players not wearing the VR headset were often encouraged to share directions with their partner. Successful gameplay did not require players wearing the VR headset to share all of the directions they were given, but we found that some participants did so anyway. Overall, we found that some teams were more inclined to share information freely with each other, whereas other teams were more reserved and sometimes needed to be prompted to share information with one another.

Open & Closed-Ended Questions

Adult participants tended to ask significantly more questions than youth participants at every decision point within the VR activity. This was due in large part to the fact that adults—with the exception of the two instances where two youth players were paired together—were always the ones not wearing the VR headset, and their role required them to ask questions about what the player wearing the VR headset was seeing. With that in mind, question-asking was perceived to be more related to the role that the participant was playing rather than associated with them being an adult or youth participant.

Explanations Beyond Text

While youth participants did not ask many questions, we found that they spent a lot of time talking through their actions and the decision-making process. Adults spent a lot of time *describing* the decision points tasks to their partners.

References to Other Experiences

During the video analysis process, we sought to note instances where study participants referenced the *When Whales Walked* video or the hands-on activities that were included as part of the Fossil Festival events. References to outside or personal experiences were also recorded. Ultimately, only a few participants referenced the video and no participants referenced other activities they'd experienced at the Fossil Festival event. It is worth noting, perhaps, that many of the study participants arrived just in time for their pre-scheduled session and therefore many had not had an opportunity to experience other parts of the Fossil Festival event beforehand. Among those who referred the video, they did so most often at the first decision point, when participants saw the fossilized skeleton for the first time.

The majority of other references to personal experiences were made by adult participants, and almost entirely during final segment of the experience wherein players were immersed in a recreation of ancient Pakistan and were able to interact with the virtual Pakicetus. At that stage, participants often reverted back to thinking of this creature as a dog and referenced personal experiences with dogs, despite having just discovered the creature's closer ancestral connection to modern-day whales.

Interview Findings

Each team of players was interviewed after completing the VR experience and the notes and recordings from those interviews was then reviewed to identify trends related to a few key themes, including enjoyment, learning outcomes, STEM understanding, awareness of what scientists do, thoughts on the collaborative nature of the VR experience, and insights into the roles that different players took on during the VR experience. Findings related to each of these themes are presented below.

Enjoyment of the VR Experience

All participants responded that they enjoyed the VR experience. The interactive scene at the end of the VR experience wherein the player wearing the VR headset could interact with the virtual Pakicetus was particularly popular—especially with youth participants. Many children said they would recommend it to friends and several asked to play a second time. Multiple participants (including youth and adults) also asked if someone would be making more “levels” or other scenarios to work through. On a related note, most participants indicated that they found value in working through the process collaboratively. The following are examples of relevant quotes from the interviews:

- “I liked the collaborative aspect...we could both talk about what we were seeing and, from a learning perspective, I think that’s helpful.” (Parent in Albuquerque, NM)
- “It was really cool to have to work with someone else to figure out what the animal was.” (Child in Albuquerque, NM)

Learning Outcomes from the VR Experience

When asked to identify things they learned, children most often identified facts related to whales, evolution, paleontology, or the Pakicetus specifically. Several adult participants said they learned about whale bone density.

It was often difficult for participants who saw the video before completing the VR activity to distinguish *where* they learned certain information. Some who saw the video first said they didn’t learn anything new from the VR experience—as evidenced by the following quote:

- “If we didn’t watch the video it would have been much more novel information.” (Child in Lincoln, NE)

However, participants readily noted that seeing the video first had given them insights into the fact that something that walked on four legs and looked a little like a modern-day dog could actually be an ancient ancestor of modern-day whales. Adults and children alike frequently acknowledged that seeing the video had had an impact on the decisions that they made during the VR experience—though some also admitted that they were thrown off by thinking the solution couldn’t be the same as what they had learned about in the video. These findings align with what was observed—especially decisions that were made by participants who had viewed the video prior to the VR experience. Together, these findings suggest that the video was somewhat successful at helping participants overcome visual biases and pre-conceived notions when it comes to determining which animals are most closely related.

After viewing the video, participants who did the VR activity first frequently noted that they paid more attention to the video, and the VR experience seems to have primed them for a more meaningful video

viewing experience. There is only anecdotal evidence for this being a trend since the interviews were optimized to compare differences in the VR experience between participants who watched the video *before* doing the VR activity in contrast to those who did not view the video beforehand. Therefore, the interviews always occurred after the VR experience; there was no formal data collection *after* participants in the later group had finished watching the video. These comments were frequent and emphatic enough to indicate the potential value of a future study set up to investigate the impacts of VR experiences on subsequent video viewing, i.e., *following* a VR-based co-learning experience. Furthermore, findings from this evaluative study suggest that such interactive co-learning experiences could be an excellent primer for more purposeful and engaged video viewership.

STEM Understanding and Awareness of What Scientists Do

When asked what they did during the VR experience that was “like a scientist,” children frequently referenced their use of the brush and scanner tools. They also referenced making hypotheses, and analyzing and comparing fossils—often with some specific prompting from their adult partners to think more about the things they had done after uncovering the fossil. The following are examples of things that children said that they did in VR that was like what a scientist does:

- “Dust off the sand from the skeleton.” (Child in Albuquerque, NM)
- “I had to find bones and analyze them to find out what animal it was related to.” (Child in Knoxville, TN)

Thoughts on the Collaborative Nature of the Experience

Both adults and children described the experience as collaborative, with each team member contributing something specific that was vital to the team’s success. As mentioned above, the collaborative nature of the experience was something that participants noted they appreciated and enjoyed about playing *Deep Time Detectives* together.

Thoughts on Participants’ Roles During the VR Experience

Even though the VR experience was designed to be collaborative, there was often one player who spearheaded efforts to prompt the other player for a response at key decision points. Parents often noted that they controlled the *flow* of the play sessions—because they were playing the game role that required them to do so—however, they still tried to defer to their children when making key decisions. In other words, some observed trends seemed to be a factor of the in-game role, more so than by-products of parent-child dynamics—though those likely came into play as well in ways that weren’t always readily discernible or clearly communicated by participants.

Adults felt they had asked more questions, but children felt that they were “working hard” in their role as field scientists throughout the VR experience. This sentiment is playfully articulated in the following quote:

- “I was the one out on the site, I’m pretty sure you [referring to the parent] were back at the shop...I was doing all the hard work!” (Child in Knoxville, TN)

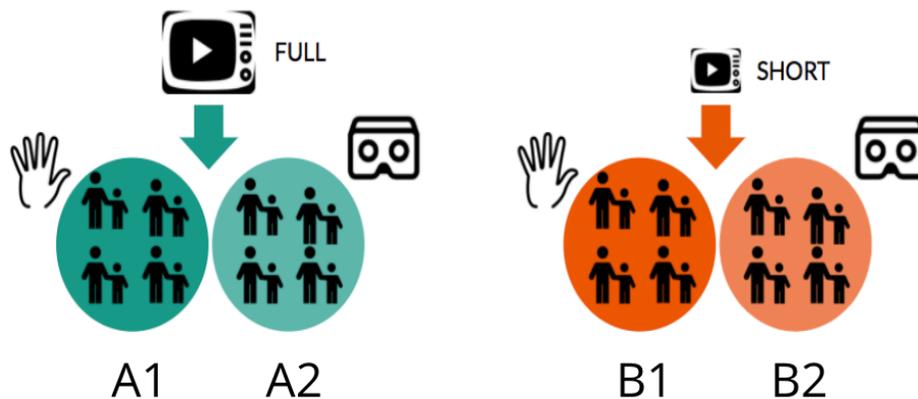
Ultimately, both players on the team cited above felt that they had an important and meaningful role to play in the team’s ultimate success. This was the case for other teams as well.

EVALUATIVE STUDY TWO: EFFECTS OF LONG VS. SHORT VIDEO VIEWING ON RESULTING VR GAME-PLAY OR HANDS-ON ACTIVITY

Methods

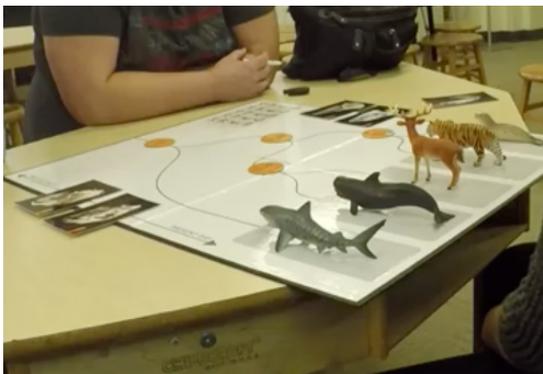
The second evaluative study sought to compare and contrast the effects of viewing the full *When Whales Walked* video vs. the shorter version of the video that focused on whales and their ancient ancestors. Participants were asked to watch an assigned video—either the full video or the shorter video—before coming to a prescheduled session at the National Museum of Natural History. During those sessions, half of the participants in each group were invited to complete the VR experience and half were invited to do the *Marine Revolution* hands-on activity, facilitated by a Deep Time Science Education Specialist at NMNH. An interview was conducted with each family at the conclusion of the session. An evaluator took detailed notes and the sessions were video recorded to facilitate further coding and observation of trends.

Figure 14: Visual Overview of Participation Conditions for the Second Evaluative Study



Participants

A total of 16 parent-child teams were recruited to participate in the second evaluative study, however only 14 came to the museum to complete the study—including seven who had watched the full video and seven who had watched the short version of the video. Four from each group were assigned to do the VR activity and three from each group were assigned to do the hands-on activity.



In the *Marine Revolution* hands-activity, participants were first asked to identify which animals they thought were most closely related in terms of shared evolutionary ancestors. They were then presented with a series of images of the animals' skulls and asked to note traits related to the shape and composition of the skulls (i.e., bone or cartilage) and tasked with using that information to fill out an evolutionary tree diagram. In doing so, they came to see that whales and deer are most closely related. In the second part of the activity, participants were asked to hypothesize whether the closest ancestor of a whale, among a new set of creatures, had lived on land or in water. They were then given sets of fossil evidence for those creatures and asked to compete a new evolutionary tree to determine if their hypothesis had been correct.

Findings

There were no observable differences between the impacts of viewing the short video program and full video program. Many participants in both groups recognized the Pakicetus and had been primed to realize that creatures that look the same are not always the most closely related, but that information was covered in both versions of the program. Rather than suggesting that there are limited benefits to viewing the entire program, these findings suggest that a short video-viewing experience before either activity is sufficient to provide similar benefits to activity participants.

Participants in this study reported that they liked working together to complete either the VR experience or the hands-on activity. Parents typically deferred to their children to make key decisions—or be the ones to decide if there was not agreement at a given decision point. Families who viewed the shorter video were also curious about what was covered in the full-length video and, to a more limited extent, those who saw the full-length video program beforehand were curious about what was covered in the shorter version.

Findings Related to the VR Experience

Play-patterns and outcomes that emerged from participants who were assigned to complete the VR experience were very similar to those that had been observed as part of the preceding study (i.e., video or no-video viewing before the VR experience). As a result of viewing either the full or short version of the video, participants were more readily able to recognize the fossil as a whale ancestor, or Pakicetus specifically. For example, one youth participant explained that they thought the Pakicetus looked like a dog, but recalled that “in the movie they say ‘it may look like a dog!’”

- “If I hadn’t seen the film, I don’t think I would have guessed it was a whale.”
- “It kind of looked like a dog but I remember it saying that the whale, before it evolved, looked almost like a dog.”
- “[The fossil] was clearly in the same family that it [the movie] talked about.”

Participants also recalled specific details about *how* scientists had confirmed that the Pakicetus had been an ancient whale ancestor based on evidence gathered from the fossil’s ear bone.

- “I remember from the film it talked about whale’s ears are made so they can hear better underwater.”
- “When it said look at the ears, I was sure it was a whale!”

Participants noted that they found both versions of the video program to be engaging and noted the fact that seeing the video—either the full *When Whales Walked* program or the shorter version that had focused on whales—had been helpful and led them to engage more fully in the VR experience. The following are examples of additional comments made by participants about the video:

- “It’s like you re-play the movie.”
- “After watching the video it was kind of cool to know what was going on.”

Hands-On Activity

Ultimately, watching either the short or full version of the *When Whales Walked* video program beforehand seemed to make participants a little more open to the idea that things that look like each other may not necessarily be most closely related. Nonetheless, despite having seen a related video beforehand—most participants did not group the sets of animals correctly the first time. Participants based their initial grouping on a variety of traits, but none of the teams paired the whale and deer together. Instead, participants tended

to pair the deer and tiger together because they both walk on four legs. Likewise, they tended to pair the whale and shark together because they are both ocean-dwelling mammals.

During the second half of the activity, when using the sets of 3D-printed bones, we found that participants often started by going through one box at a time. To more effectively enable comparisons, the facilitator encouraged them to compare specimens from different species. Once they realized that they needed to consider one trait at a time and look at all the specimens, participants were usually fairly successful at coming to successful conclusions, with the exception of discerning the location of the nostrils on either the top or end of the skulls. Youth participants seemed to grasp the structure of the evolutionary trees more quickly than adult participants. They were also more likely to place the traits accurately based on observations they made using the 3D-printed fossil replicas.

After they finished the activity, participants were asked what they'd done that was like a scientist. Responses included: making mistakes, examining artifacts/looking at fossils to figure out which are related, looking for evidence, asking questions, making hypotheses. The following are statements that were made by two parents:

- "I thought it was cool. The tree is a really great way to graph evolution because it reminds me of people who do family trees - its like one big ancestral family."
- "It wasn't trivial. There was some real thinking and I got it wrong a couple times where she got it right. It was engaging...[it] required some real analytics work."

Comparisons and Contrasts between Video and Hands-On Activities

One of the key differences with the hands-on activity, in contrast to the VR activity, was the fact that it was led by a skilled facilitator. This allowed for more flexibility in the decisions that were made by participants—though the facilitator noted there were somewhat consistent patterns in terms of decision-making and discussion around decision points. Nonetheless, participants were free to make decisions that were incorrect and the facilitator would carefully help guide them to the correct conclusion through a series of questions or prompts. The later point—i.e., the facilitator's ability to help correct participants' misconceptions and provide examples or information that helped to clarify their thinking—was another key difference for families who completed the hands-on activity. Likewise, those who completed the hands-on activity also had the ability to ask the facilitator questions. The VR experience, on the other hand, was all pre-scripted and self-guided. The decisions that were possible at different points were pre-set. In contrast, the hands-on activity allowed participants to take different paths to discovery, whereas participation in the VR activity followed a more linear path to discovery.

There seemed to be more conversation between team members during the hands-on activity than during the VR experience. Even though they technically had different roles in the *Marine Revolution* activity, we found that most participants completed the tasks together, whereas the presence of only one player in the virtual world created a greater distinction between participants in the *Deep Time Detectives* game condition; only the player wearing the VR headset got to see and "handle" the fossils, whereas both players got to look at the fossils in the *Marine Revolution* activity—ultimately facilitating conversation and more equitable decision-making opportunities.

Lastly, we noted that participants who did the hands-on activity were more likely to reference or note things they had learned about phylogenetic trees. Several of the participants in the hands-on group reference the tree of life as something they had learned about. The VR experience did not place as great an emphasis on use of that tool.

CHAPTER 3: IMPACTS ON ISE PROFESSIONALS

The evaluation sought to determine the efficacy of training and support provided by staff at the Smithsonian's National Museum of Natural History to ISE professionals.

METHODS

Members of the evaluation team observed a training session for Fossil Festival facilitators in July of 2019 and worked with participants to identify goals for their events and any additional information they hoped to learn through the evaluation of their events. As part of site visits to seven subsequent Fossil Festival events in 2019 and 2020, REA staff conducted post-event interviews with Fossil Festival facilitators and volunteers. To determine longer-term impacts, follow-up interviews were also conducted with 11 Fossil Festival facilitators and volunteers in February of 2021. Lastly, members of the REA evaluation team observed an online training session for ISE professionals that was held in September of 2021 and gathered post-event feedback from participants via an online survey.

FINDINGS

Findings related to the facilitator training session

Observations of the training session held in the summer of 2019 and fall of 2021, together with data from post-training surveys and post-event interviews suggest that ISE professionals appreciated the care and thought that went into developing activities and resources that could be used by informal science educators to help members of the public better understand evolution and various related principals. Training session participants' prior understanding of evolution varied, but the training programs were successful in making the content accessible for all.

Getting to experience each activity as a participant was valued by training session attendees. Also, as a result of the training experience, participants came away feeling more knowledgeable about evolution and more confident in their ability to share information effectively with members of the public—even in communities where there may be some resistance or hostility toward the theory of evolution. One facilitator stated her appreciation, specifically, for the guides they received, and the role-playing she'd had an opportunity to do with other attendees—those opportunities helped alleviate concerns about hosting a large, multifaceted event.

Training session attendees also said that networking with other professionals had been valuable as a means of establishing mutual support and a collaborative professional community. Some participants noted that they are still in communication with other facilitators who were trained in the same cohort. The training session held prior to the Fossil Festivals also encouraged participants to establish partnerships with other cultural and educational institutions and ultimately increased awareness of how to host an event with diverse populations.

- “What I did gain was the in-person meeting with everybody else who was doing this. That was fabulous. The in-person knowledge of the people presenting the information, it was fabulous to have those contacts.”
- “We have used those connections that we've made there since then, for other things, like the group in Nebraska, we've been working with them. It is the contacts for me, that has been invaluable. And being able to use those contacts later, in a wide variety of ways is amazing.”

Findings related to facilitators’ perceptions of event success

Across the board, Fossil Festival facilitators felt that their events had been successful. The number of attendees was something cited by many facilitators as an indicator of the success of their events. For example, one facilitator explained that her team had been expecting four-hundred people but there were more than 700 participants who came to their event. She elaborated:

- “I was exhausted, but at the same time, so happy that day. I cannot believe how many people showed up. First of all, attendance was off the roof. This is the highest attendance we've ever had for a family (event).”

Facilitators also saw positive things happening at the events—e.g., interest in STEM being sparked among youth attendees—and got lots of encouraging feedback from families. One facilitator noted that parents told her they did not expect the event to be as big and as exciting as it was and many had anecdotes about parents who had a hard time getting their kids to leave.

- “We had some families who brought their own middle schoolers and kindergarteners, and everyone had lots of activity to take in and participate in. It wasn't just that they kind of came in, got bored and in 20 minutes left. People were there for a couple hours.”
- “I just enjoyed the experience and hopefully they can partner with us again...the kids really benefited from the experience.”
- “Many of the experiences made [kids] want to be scientists.”

Strength of Co-Play/Co-Learning Activities and Resources: Facilitators appreciated that the activities designed by Smithsonian staff had been designed to encourage family co-play and co-learning. Many of the facilitators favorably recounted instances where family members were participating together in activities and the parents were just as excited and engaged as their children were. In fact, facilitators played a key role in helping to ensure parental engagement:

- “It wasn't just the kids that [the facilitators] were engaging, they would ask the parents questions, or, have them participate in whatever it may be. And I know that VR was set up so that the parent also played the game with the kid. I thought that was really cool to see parents on the floor with their kids doing the activity. Parents were as excited as the kids about the activity.”

One facilitator noted that parents usually “come and they're used to that model of 'this is for my kids, this isn't for me, my kids are going to go play and learn science, and I'm going to stand here and watch,’” so they sometimes had to be encouraged to participate. After doing so, she noted that “it was really fun to see how

excited the parents got, especially with that elephant activity, they really got into it...so, it was good to see the adults kind of getting excited about science, too.”

Another facilitator said that she observed a far lower percentage of parents sitting on the sidelines or on their phones. She noted that family members were all participating together—“compared to other events, the amount of intergenerational engagement in an activity was off the charts and parents and grandparents and aunties and uncles were all engaged with it. The kids, the grandkids, nieces and nephews, they were all engaged together.” A volunteer at the two events held in Knoxville also noted a lot of cooperation between children of all ages and observed them helping each other and engaging with each other during the activities.

Facilitators stated that event participants of all ages enjoyed the VR experience in particular. Likewise, they appreciated being able to hold and touch the 3-D printed replicas of fossils as part of the hands-on experiences.

- “Kids got the opportunity to participate in the virtual reality. Because these are students in a Title One school, you just don't necessarily have access to technology. So, I think that was a really cool experience and the kids were so stoked about it.”
- “We all fell in love with the activities and we want to be able to keep using them...I fell in love with some of those games, thinking that these would be great for our homeschool days, utilizing some of the fossils that we have at the museum that they could touch and work with, and then explore some of these topics related to evolution in a kind of low-stakes setting. I think the games were really good at making a controversial topic very low-stakes because it was animals that you don't necessarily think about evolution being associated with.”

Event Attendance and Attendee Diversity: Organizers were happy with participant attendance and their events’ ability to engage participants of all ages. Furthermore, facilitators felt that they had been given the tools and resources to successfully reach and serve diverse and multicultural audiences.

Many of the facilitators said that the strategies and training that they received prior to hosting their events fostered professional practices that helped them to draw in more attendees. Specifically, grant funding and training helped event facilitators market to underserved and diverse communities that had been challenging to reach in prior events. As a result of the training they had received, Fossil Festival facilitators sought to learn more about the diverse groups they were seeking to serve in order to support the multicultural and multilingual needs of those audiences. Grant funding as part of the Lineage program also helped pay for advertising that had a big impact on attendance and helping sites reach underserved audiences that they had had a hard time reaching previously. Money for marketing helped one team place ads in local papers, and in *The Navajo Times*, and to talk with a Navajo radio station.

- “This is the first event where I feel like we effectively marketed an event, because we were supported by the Smithsonian, and there was the ability to use some money towards marketing. And that was an amazing thing to see in terms of results we got, because that made a world of difference of who we could reach and how we could reach them.”

Because sites were able to promote the event to diverse audiences, festival facilitators said that they had to find strategies to support the multilingual and multicultural audiences that ultimately attended their events. In

addition to engaging the local Hispanic community with Spanish signs and Spanish-speaking volunteers, one team of facilitators also sought to engage the local Navajo population more effectively by being aware of Navajo cultural norms and history and by having Navajo speaking volunteers present to address the unique needs of Navajo attendees.

Another event facilitator decided to support the needs of Spanish speakers by involving a group of bilingual student volunteers—many of whom were Latinx women. She said that this helped children, especially young Hispanic females, have the opportunity to see themselves reflected in the volunteers and to realize that Latinx woman could be scientists too. A native Spanish speaker herself, this facilitator was also able to help create signs and materials in Spanish and also came up with the idea of making stickers that Spanish speakers could wear, so that Spanish-speaking volunteers knew to speak to them in Spanish and make sure they felt included and acknowledged at the event.

One facilitator said that the Fossil Festival events were helping new audiences get to know the museum because she saw many of the same families attend both events that were held in their community. She and other volunteers made sure to engage with Spanish-speaking families who had also attended the earlier event in their community. “I think there was a very intimate connection with some families,” she explained. She credits these strategies with helping to successfully engage the Hispanic community and in making the Fossil Festival a popular multicultural event.

Highlighting local treasures and resources: One participant said the the training offered at NMNH had helped her learn how to incorporate organizational resources such as books. For example, she explains: “one of the things that we did is set up our wonderful book displays, and it was a great time to be able to showcase a lot of the technology and a lot of the programs...to show how we expand into literacy. It was a great program to be able to connect back to museums and show how libraries and museums can work together.”

Overcoming cultural aversion to certain topics and activities: Because of diverse cultural and religious beliefs in the communities where the festivals took place, some sites faced challenges with cultural norms and were very sensitive to the strategies that they used in presenting the theory of evolution—in some cases avoiding reference to the term evolution. Some sites changed the name of their program from Fossil Festival to “Family Festival” or “Fossil Fiesta” so that the events could appeal to as many families and different cultures as possible. For example, in Knoxville, the McClung museum incorporated the Fossil Festival as part of their annual Darwin Day event, but due to input from teachers and administrators at the elementary school they partnered with, they ultimately decided to change the name of the festival that was held at Norwood Elementary to “Family Festival.” Likewise, they opted to use the wording “change over time” when they were talking about evolution at that event. In doing so, they hoped the experience would be more appealing to families with different positions on the theory of evolution due to cultural or religious beliefs. A facilitator of that event stated the following:

- “There was a general sense that if we put the name ‘fossil’ out there, maybe people would think twice before attending the event. We just want it to be very gentle, because it’s relatively new relationship with the school. And that was the feedback from the coordinator, and from the teachers.”

In New Mexico, facilitators faced the challenge of overcoming cultural taboos against touching bones. A facilitator of the events in that state said she saw youth attendees at her event explaining to Navajo parents and elders that the bones were 3-D replicas so it was okay to touch them.

- “It ended up being a good experience for the student volunteers who were nervous to talk about evolution, because as volunteers they have also been in situations where they felt cornered, or they felt like they need a lot more help facilitating conversations. But at the end of the day, they were so happy to engage with the families in the school environment, and it went really well without any controversy.”

One facilitator noted that the experience of helping to host two events in her community had given her added confidence in her ability to effectively address controversial issues. She explained that she was initially concerned that the content was too controversial for her local community, but she said that the training helped her successfully present and manage the event. She also said that she learned how to train others in proactive ways about controversial subjects and learned how to work effectively with different event partners.

Dealing with set-up logistics and wait-time associated with VR experiences: Facilitators also noted some of the logistical challenges associated with setting up and running the VR equipment, managing crowd flow, and other activities that took a while to complete. They were appreciative of technical support for the VR experience that was offered by members of the Schell Games development team.

- “The setup with the technology was challenging, and there was a lot of sort of interface issues at both sites, just to get the technology up and running. But once it was up and running, it was fine.”
- “We didn't realize how long it was truly going to take between them or how to schedule that. Part of that is just everyone's enthusiasm for wanting to try it. That which, in some ways is a good problem to have. But it would have been nice if we could have figured out a way to meet more people's needs with that.”
- “Our biggest challenge was how do we entertain everyone else while they are waiting to be able to play some of these games, and how do we get it to be so that they can cycle back through and get a chance to play these and they're not just like cycling back there at a time when someone has just started, or someone is halfway through?”

Findings related to plans for future use of resources and strategies from Fossil Festivals

All of the facilitators said that they will continue to use, or have used, techniques and activities that they learned during their training. One facilitator noted that exploring the Smithsonian's National Museum of Natural History was her favorite part of the training because it inspired ideas that she was able to bring back to her institution. Since her event she has also run other events in a similar way—putting exhibits and activities in different areas of the library and showcasing different careers—she's even found ways to incorporate other virtual reality activities.

Greater emphasis on family learning experiences: Facilitators said that they came to find new or renewed value in focusing on families as the target for engaging informal science learning experiences. One facilitator argued that her museum should not just focus events for children, but should focus on events and activities that meet the needs of the whole family and diverse groups of people. Otherwise, she noted, the museum would be missing out on valuable and meaningful educational and outreach opportunities that could serve many people of all ages and backgrounds and foster greater interest in science. Site facilitators also realized

that they had to adapt activities to appeal to, and be effective for, participants of a wide range of ages and knowledge levels.

- "In the past, pre-Lineage, I had always thought of it as a scientist or educator-child interaction, and seeing the model of the Lineage activities where you can help that parent be so strongly involved in the interaction, it was really valuable, I would say, just for my own professional development, and for our museum and for unity to get engagement in science learning in that way."
- "It's one thing to reach out to the kids and get them excited about science, but if you have a family member who doesn't see the importance, or doesn't understand why the child is excited about it, the fostering of learning might not continue at home. So, I think it just really switched our perspective of thinking whole family not just individuals."
- "Kids will bring in the families. And even if you request eight to 12 year olds, you're still going to get the teenagers, you're still going to get the adults, you're still going to get bilingual families, you're still going to get a variety that you're not just not expecting, you might get an anthropologist, you might get a paleontologist, educator, and so you want to be able to create something for everyone."

Effects of COVID-19: Shortly following the final Fossil Festival event held in early 2020, the county went into a temporary lock-down in response to the COVID-19 pandemic. Many of the facilitators we spoke with suggested that they would have made more use of the Lineage activities and resources had it not been for COVID. However, even though preventative measures such as social distancing made it impossible to host large in-person events for an extended period of time, the family engagement techniques one facilitator learned from her experiences through the Lineage project inspired her to create virtual versions of activities that could be shared with participants online.

CONCLUSION

In addition to creating high-quality resources and delivering a series of events to members of the general public and offering training sessions for ISE professionals, the Lineage project sought to:

- learn more about the outcomes of Fossil Festivals,
- learn about the impact of video on family's co-play experiences and the video program's ability to help parents grasp and explain challenging or abstract concepts to children, and,
- learn about programmatic impacts on ISE professionals who were engaged in the project in various ways.

The following is a brief summary of key findings related to each of the subsequent evaluation questions.

STEM-Related Outcomes

The evaluation sought to determine whether the Fossil Festival experiences increased participants' understanding of specific topics or STEM in general, whether participants felt more comfortable with STEM, and whether participants came to be more interested in STEM and other STEM-learning opportunities. Survey and interview findings from family members who attended the Fossil Festivals suggest that they did. Observations of events revealed that families were learning about STEM in general, as well as specific facts and concepts related to evolution. Family members—young and old alike—were coming away with a greater sense that creatures that look the same aren't necessarily the most closely related. They were also learning more about how scientists study evolution and *why* they do so.

Additionally, the evaluation sought to determine whether participants came to be more aware of the role that STEM plays in their life. Many participants came to be more aware of the connection between modern day creatures (including humans) and various ancestors that evolved over time. The fossil pollen hands-on activity (*Tiny Fossils: Big Picture*) in particular, proved to be a resource that helped participants become more aware of the role that STEM plays in their lives, insofar as it helped participants see how changes in the world around them could impact the creatures—including humans—living in a given environment. Additionally, many youth participants who attended the Fossil Festival events came away with greater awareness of different types of STEM professionals—i.e., a first step to possibly pursuing STEM careers down the road.

Co-Learning Experiences

The evaluation also sought to examine whether parents came to feel more empowered to support their children's learning, and whether participants came to feel more empowered to learn together as family units. Being able to participate together was something frequently mentioned by participants as something they appreciated and enjoyed most about the Fossil Festival events and the various activities they were able to engage in as part of those experiences. Even though it sometimes required a little encouragement or prompting to get adults engaged in activities alongside children, event facilitators saw many adults actively engaging in activities alongside youth participants at their events. On a related note, many STEM professionals who helped facilitate Fossil Festival events said that these experiences led to a new or renewed awareness of ways to provide informal science learning experiences that serve the needs of diverse audience

members—allowing family members to learn alongside one another, but also allowing diverse members of the community to engage more fully and effectively in ISE programming.

Impacts on ISE Professionals

The evaluation sought to determine whether, and to what extent, the program had an impact on ISE professionals and there is evidence to suggest that there *were* meaningful and perhaps long-lasting impacts. In addition to promoting greater awareness of the value of family co-learning experiences, the Lineage program also provided ISE professionals with additional skills and resources to support effective intergenerational learning.

ISE professionals who helped to organize Fossil Festivals in the six regional sites noted that the program had helped them become more aware of diverse audiences and gain more awareness of how to market to and address the needs of those audiences. Event facilitators indicated that the Fossil Festival events that they'd hosted as part of the Lineage project were among the best attended and most successful events they'd ever held. As soon as the COVID-19 pandemic allows things to return to normal, they look forward to building upon the knowledge they gained and resources that they acquired through the Lineage project.

Impact of Video on ISE Experiences

Through two evaluative studies, the evaluation team sought to explore the impacts of video programming on other ISE experiences including a VR experience and hands-on learning experience. In the first of two studies we sought to examine whether there were differences among participants who watched a short video before doing the VR activity in contrast with participants who didn't view the video beforehand. As anticipated, we found that watching a portion of the *When Whales Walked* video program before the VR experience provided participants with insights into the fact that something that walked on land and looked like a dog could actually be an ancient ancestor of modern-day whales. There were discernible differences between the types of hypotheses and decisions that video-viewers made when completing the *Deep Time Detectives* VR experience in contrast to participants who had not viewed the video program beforehand. Additionally, despite the fact that this study was not set up to consider the impacts of the VR experience on *subsequent* video viewing, anecdotal evidence emerged to suggest that the VR experience led participants to be more engaged when they watched the video *after* completing the VR activity.

In the second of two evaluative studies we sought to examine the impacts of viewing the full *When Whales Walked* program in contrast to the shorter version of the video that was used in the first study. Findings from the later study suggest that outcomes of viewing the shorter version of the video were similar to those of viewing the full video program. The later study also provided opportunities to compare and contrast the hands-on activity experience and the VR experience. We noted that there was more discussion among team members as they completed the hands-on activity—due in part to there being less division of participant roles within the hands-on activity since both participants could ultimately see the same things. We also noted the benefits of being able to engage directly with an ISE professional who served as a facilitator for the hands-on activity in contrast to the VR experience that was self-guided. Among the key similarities between the hands-on and VR experiences were team members' enjoyment and appreciation of the opportunity for family members to engage in the activities together.

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APPENDICIES

APPENDIX A: SURVEYS

FOSSIL FESTIVAL PARTICIPANT SURVEY EXAMPLE

Fossil Festival Participant Survey – Tennessee

This survey is part of an ongoing evaluation of educational programming funded through a grant from the National Science Found. Data will be used to inform project reports and presentations. Your voluntary completion of this survey, (which should only take about 5-10 minutes, and shouldn't pose any harm to you), indicates your acknowledgement that you are willingly participating in the evaluation process.

Questions for Families:

About Your Experience at the Fossil Festival

1. Overall, how much did your family enjoy this event?	Not at all	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5 A lot!
2. How much did your family enjoy each of the following activities today?	Didn't do this one	If you did this activity, how much did you enjoy it? Not at all A great deal				
a. Virtual Reality Game: "Deep Time Detective"	<input type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
b. "When Whales Walked"/Lineage Film	<input type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
c. Whale Activity - "Marine Revolution"	<input type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
d. Elephant Activity – "Elephant Evolution"	<input type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
e. Pollen Activity – "Tiny Fossils, Big Picture"	<input type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
f. The "Gray Fossil Site" tables	<input type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
g. Craft activities	<input type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
h. Other activities	<input type="radio"/> 0	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5

3. Please use the space below to share additional comments about the activities that you did today.

Please continue on the back ⇨

- Continued from front -

4. How much did your family **learn** at this event? *Nothing at all* 1 2 3 4 5 *A lot!*

5. What did you **learn** at today's event?

Questions for Parents

6. To what extent did this event....	Not at all	A great deal			
a. ...make you feel more comfortable with science?	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
b. ...help you see connections between science and your life?	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
c. ...help you feel more capable of helping your child(ren) learn about science?	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5
d. ...help your family learn about science?	<input type="radio"/> 1	<input type="radio"/> 2	<input type="radio"/> 3	<input type="radio"/> 4	<input type="radio"/> 5

About Your Family (For questions 7-9, please **check all options** that apply)

7. Are you a member of a local **museum**? I am My family is Another member of my household is

8. Are you a member of your local **PBS** station? I am Another member of my household is

9. Do you have a **library card**? I do My child does/children do Another member of my household does

10. How long did it take you to get here from your home?

less than 5 minutes 6-15 minutes 16-30 minutes 31-60 minutes more than an hour

Post-Training Workshop Survey

1. What is your current comfort level reading or understanding evolutionary (phylogenetic) trees?
 - Don't do it/avoid it
 - uncomfortable
 - comfortable
 - very comfortable
 - don't know
2. What is your comfort level teaching evolutionary concepts to museum audiences?
 - don't do it/avoid it
 - uncomfortable
 - comfortable
 - very comfortable
 - don't know
3. Based on this workshop experience, how likely is it that you will integrate evolutionary (phylogenetic) trees into teaching or communicating evolutionary concepts?
 - don't plan to do so
 - not very likely
 - somewhat likely
 - very likely
 - unsure
4. How do you anticipate integrating evolutionary (phylogenetic) trees into your teaching and communicating of evolutionary concepts?
5. What were the main things you learned from this workshop?
6. What, if any, lingering questions do you have about evolutionary (phylogenetic) trees, incorporating phylogenetic trees into your teaching, or other concepts that were presented during this workshop?
7. How likely would you be to recommend this workshop to a colleague?
0 (not at all likely) 1 2 3 4 5 6 7 8 9 10 (extremely likely)
8. Please use the space below to share any feedback that you have about the workshop.
9. Is there anything that the facilitators could do or provide that would help you make use of the information and resources that were shared during this workshop?

APPENDIX B: INTERVIEW PROTOCOLS

Post-Activity Participant Interview Protocol

1. What did you think about this activity (film)? Prompt for likes/dislikes and anything they didn't understand?
2. Tell me (a little more) about what you did in this activity? What was your role in the activity? (ask adult and child)
3. Did you like doing this activity together? Why/why not?
4. Who would you say was more "in control" or "in charge" of this activity?
5. Did you do anything that a scientist does? (Did you use any tools methods that a scientist uses? Did you form hypotheses? What did you hypothesize? Was that right/wrong? How did you know?)
6. Did you learn anything from doing this activity? (Did you learn anything about evolution/how _____ changed and adapted over time?)
7. Is there any other feedback you'd like to share about this activity (film?)

Note: For logistical reasons, including ambient sound, evaluators were not able to obtain clear recordings of all interviews. Notes were used for analysis purposes in instances where it was not possible to use recordings for analysis.

ISE Professional Interview Questions

1. What were the strengths of the Fossil Festival at your site?
2. Were there any weaknesses?
3. What challenges did you face in developing your Fossil Festival?
4. What challenges did you face in implementing your Fossil Festival?
5. What were some of the participant-level impacts that you observed or heard about?
6. To what extent did this experience enhance your site's ability to support family-learning?
7. Did the training you received from the Smithsonian adequately prepare you to host the Fossil Festival at your site? Is there anything else that you wish the training had included?
8. Did this experience spark any interest in hosting future events of this nature at your site (or other site?) (have you done any related activities or events that build on the work you did in 2019/2020 as part of your Fossil Festival?)