International Journal of Science Education, Part B
Communication and Public Engagement

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rsed20

Learning from the real versus the replicated: a comparative study

Laura D. Carsten Conner & Suzanne M. Perin

To cite this article: Laura D. Carsten Conner & Suzanne M. Perin (2020) Learning from the real versus the replicated: a comparative study, International Journal of Science Education, Part B, 10:3, 266-276, DOI: 10.1080/21548455.2020.1831707

To link to this article: https://doi.org/10.1080/21548455.2020.1831707

Published online: 05 Nov 2020.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, PART B
2020, VOL. 10, NO. 3, 266–276
https://doi.org/10.1080/21548455.2020.1831707

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Learning from the real versus the replicated: a comparative study

Laura D. Carsten Conner [a] and Suzanne M. Perin [b]

[a]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK, USA; [b]College of Natural Science and Mathematics, Fairbanks, AK, USA

ABSTRACT
The nature of the learning that occurs with real versus replicated objects and environments is an important topic for museums and science centers. Our comparative, exploratory study addressed this area through an investigation of family visits to two different settings: an operating permafrost research tunnel, and a replica of this permafrost tunnel at a science center. We conducted and analyzed family interviews, grounding our work in the Contextual Model of Learning and ideas about sensory components of learning. We found significant differences between the real and replicated environments in terms of what families discussed during interviews. Specifically, the proportion of perceptual (descriptions of features or sensory-based perceptions) talk at the real tunnel was higher than that at the replica tunnel, while the proportion of conceptual talk was higher at the replica tunnel as compared to the real tunnel. The nature of the conceptual talk was similar at the two sites, and often relied on objects as 'nodes' of learning. Our findings suggest that visitors were sensorially engaged to a higher degree in the real, versus the replicated, setting. Given these findings, exhibition designers should think carefully about the goals of specific exhibit elements and privilege real objects and immersive experiences accordingly.

ARTICLE HISTORY
Received 19 December 2019
Accepted 29 September 2020

KEYWORDS
Informal learning; real objects; authenticity; sensory engagement; conceptual learning

Introduction

The question of whether authenticity matters, and how it impacts learning, has long been of importance to museums and science centers (e.g. Evans et al., 2002; Gurian, 1999), yet there is conflicting evidence in the literature on this topic (van Gerven et al., 2018). Studies show variously that visitors place value on authenticity (e.g. Bunce, 2016; Soren, 2009; van Gerven et al., 2018), or, conversely, that authenticity does not matter as much as other factors in terms of visitor experience (e.g. Hampp & Schwan, 2014; Hampp & Schwan, 2015). A few studies have taken a deep dive into the nature of the learning that occurs from and with real vs. replicated objects. For instance, Klahr et al. (2007), showed that cognitive gains among learners were similar across replicated vs. virtual objects. In another example, Eberbach and Crowley (2005) found that replicated vs. real objects support different aspects of learning, with replicas supporting more process-based explanations, and real objects engendering more connections to everyday life. However, empirical studies examining the nature of the learning that occurs with respect to real vs. replicated objects and environments are relatively rare. More studies of this kind are needed in order to effectively inform the design of learning environments, especially at museums and science centers.

CONTACT Laura D. Carsten Conner ldconner@alaska.edu 2156 N. Koyukuk Drive, University of Alaska Fairbanks, Fairbanks, AK 99775, USA

The present study addressed this topic through an investigation of family visits in two different settings: an operating permafrost research tunnel, and a replica of this permafrost tunnel at a science center. The experience in both places was mediated by an 'explainer' style tour, followed by open-ended time to explore the environment. The replica tunnel was modeled closely after the real tunnel, complete with discrete replicated objects such as ice features and bones. Close attention was paid to mimicking some sensory aspects such as the texture of the tunnel walls, and the smell of the real tunnel, although some characteristics were not present, such as the chill and dust. While museums frequently display a mix of replicated and real objects, making comparisons of visitor learning possible within the museum setting, there is rarely the opportunity to study learning in an entire replicated environment as compared to the real environment it is modeled after. This study offers just such an opportunity, and can thus offer unique insights about visitor learning with respect to both objects and the larger environment.

Theoretical framework

We ground our study in the Contextual Model of Learning developed by Falk and Dierking (2000, 2012) which has been invoked in a number of studies of learning in exhibitions. We bring ideas from this model together with ideas about affective and sensory components of learning that are brought to the fore in theories of materiality. The Contextual Model of Learning draws on both cognitive and sociocultural aspects of learning, and, as the name suggests, emphasizes learning *in context*. Specifically, three contexts are specified: physical, personal, and sociocultural (Falk & Storksdieck, 2005). In this model, what is learned from an exhibit (and the objects it contains) in terms of content or concepts is not consistent across visitors, but instead arises from an interaction of the prior knowledge, interests, and the worldview of the visitor, the characteristics of the object, and the social and physical context in which the object is experienced (Falk & Dierking, 1992). The social aspects of museum visits have been well studied. Family interactions are known to be important with respect to how individuals build on, connect to, and extend knowledge (rev. in Ellenbogen et al., 2007). Often, interactions with exhibitions are mediated by tour guides or explainers. Interactions with these museum educators have been shown to be helpful in extending conceptual knowledge, but they can limit social interaction within family groups (Cox-Petersen et al., 2003); thus, it is important to build in time for open exploration in order to receive the benefit of both types of social interactions. Importantly, visitors frequently use objects as foundations for conversation during their visits (Allen, 2002; Hein, 1998; Jant et al., 2014).

This framework thus brings the physicality of objects themselves, and their possible affordances for learning, into sharp relief. The idea that physical objects are paramount to learning reaches far back into the history of educational theory, with the idea that objects, or 'artefacts,' mediate cognition itself (Vygotsky, 1978). This object-based learning occurs through sensory engagement, as experiences with objects are mediated through touch, smell, or sight, or even a sense of 'immersion' or 'presence' in the case of entire environments (see Dede, 2009, for discussion of immersion in virtual environments). Many have argued that the ability of objects to evoke rich sensory and emotive responses illustrates that objects have special learning affordances embedded within the object itself. For instance, Dudley (2012, p. 1) describes her response to the material aspects of a Bronze Chinese horse:

> I was utterly spellbound by its majestic form, its power, and, as I began to look at it closely, its material details: its greenish colour, its textured surface, the small areas of damage. I wanted to touch it, though of course I could not – but that did not stop me imagining how it would feel to stroke it, or how it would sound if I could tap the metal, or how heavy it would be if I could try to pick it up. I was, in other words, sensorially exploring the object …

As this passage suggests, objects can engender a type of sensory engagement, and emotional response, that is bound up in the appreciation of the inherent qualities of the objects, such as size, texture, and other features. Leinhardt and Crowley (2002) also refer to the scale of an object as an important dimension of its evocative power. But there is a second important function of objects – to impart a 'knowledge of meaning,' or the idea that the object itself imparts meaning and conceptual understanding (Wehner & Sear, 2010). This idea resonates with Leinhardt and Crowley's (2002) emphasis on objects as special 'nodes' for elaborating conceptual knowledge, based on characteristics such as the 'resolution' and 'density of information' that they contain and convey. In either case, whether the object serves as a touch point for sensory engagement or a node for conceptual understanding, the nature of the object itself, or, we would also argue, the nature of an environment, has important implications for what visitors take up from their experience.

Here, we address this area by asking 'what is the nature of the learning in a real versus a replicated environment?' Specifically, we were interested in what visitors take up in terms of concepts, and the ways that visitors engage perceptually and sensorially with the environments and the objects they contain, across these two types of environments. Our study was conducted in the context of family visits in two different environments, one real and one replicated. The visits were mediated by an 'explainer,' with time for open exploration of each environment after the completion of the tour.

Methods

This exploratory study was comparative in nature, examining visitor experience at a real permafrost tunnel in Alaska and at a replica of this permafrost tunnel at the Oregon Museum of Science and Industry (OMSI). At both locations, families were recruited to visit the site and to participate in the research. Below, we describe the two study settings and other aspects of the study in more detail.

Site 1: Permafrost tunnel

The permafrost tunnel is a human-made tunnel dug into the side of a hill that is underlain by permafrost (Figure 1). From the outside, it appears as a small building set against the hillside, accessible

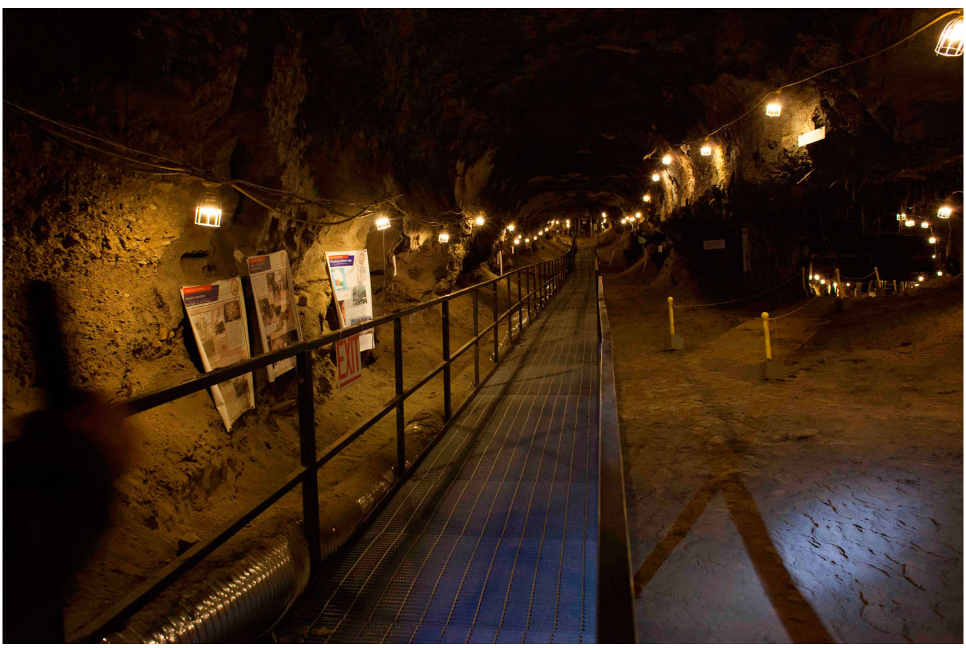

Figure 1. The permafrost tunnel in Alaska. Photo credit: A. Woodard.

by a door. The tunnel is owned and operated by Cold Regions Research and Engineering Laboratory of the U.S. Army Corps of Engineers, and primarily functions as a research space where geological, paleontological, and engineering questions are answered. The walls of the tunnel are comprised of permafrost, a complex matrix of soil and ice, with large 'ice wedges' that have formed over thousands of years. The tunnel walls also contain pleistocene bones, such as mammoth, and other remains, including plant material that is still green. The tunnel walls are somewhat irregular, reinforcing the feeling that one is inside a natural cave. The tunnel is refrigerated to keep the permafrost cold, as ambient air temperature in the different seasons is often above freezing. The tunnel is not regularly open to the public, but often hosts tours for K-12 and university-level classrooms, as well as the occasional public event. The tunnel offers the opportunity to view, touch, and learn about permafrost, which is normally underground and invisible.

There are several different kinds of sensory experiences available to tunnel visitors. In addition to seeing and touching ice wedges and bones, the tunnel has an auditory aspect from the sounds of feet echoing on the metal catwalk on the floor. The refrigeration means that there is a noticeable chill in the air. Silt is released into the air from the walls, giving the tunnel a dusty feeling, and the tunnel also has a pervasive, barnyard-like smell as old carbon is released.

The experience at the tunnel offers a new way for Alaskans to learn about permafrost. While many residents live on permafrost and are aware of everyday consequences like bumpy roads, or the need to engineer housing foundations in special ways, most people have never actually seen permafrost, nor do they know about its age, structure, or composition, as it occurs underground and cannot normally be viewed directly.

Site 2: Replica tunnel

A replica tunnel was created as part of a larger 2000 square-foot permafrost exhibition developed by the Oregon Museum of Science and Industry (OMSI), in partnership with the University of Alaska Fairbanks. The replica tunnel itself was designed to closely resemble the real tunnel in Alaska in both color and texture (Figure 2). Just as in the tunnel, there are embedded ice wedges and fossils (animal and plant material) sticking out of the walls (replicated rather than real). An image of the metal catwalk floor found in the real tunnel, slightly obscured by silt, forms the walkway of the replica tunnel. The exhibit also includes a smell station, which releases the barnyard-like smell of the real tunnel at the touch of a button.

Tours

As a research site, the permafrost tunnel is not designed as an educational environment, and thus does not contain signage or interpretive elements to convey conceptual information about the tunnel. While the structure of the tunnel walls is visually intriguing, it is not immediately clear from viewing them how these elements were formed or their age. Similarly, while extruding bones are visible, the origin and age of the bones are not clear without interpretation. In this study, a permafrost researcher offered a 20-minute tour of the tunnel, focusing on the composition of permafrost (a mix of soil and ice that stays frozen all year round), how ice wedges are formed, the age of the permafrost and the features embedded within it, including how long it took for the permafrost to form (it formed over a long time span, between 12,000–45,000 years ago), and linking thawing permafrost to greenhouse gas emissions. Throughout, the tour guide pointed to bones and ice wedges in the walls to illustrate different points. She also described the origin of the smell – as animal and plant remains that are frozen in the soil thaw out of the permafrost, they start decaying. Visitors were encouraged to touch the walls, and had time for open exploration of the space once the interpretive part of the tour concluded.

At the replica tunnel in the science center, the same researcher gave the tour, keeping it equivalent in terms of what was said, and pointing to the same features (replicated ice wedges and bones)

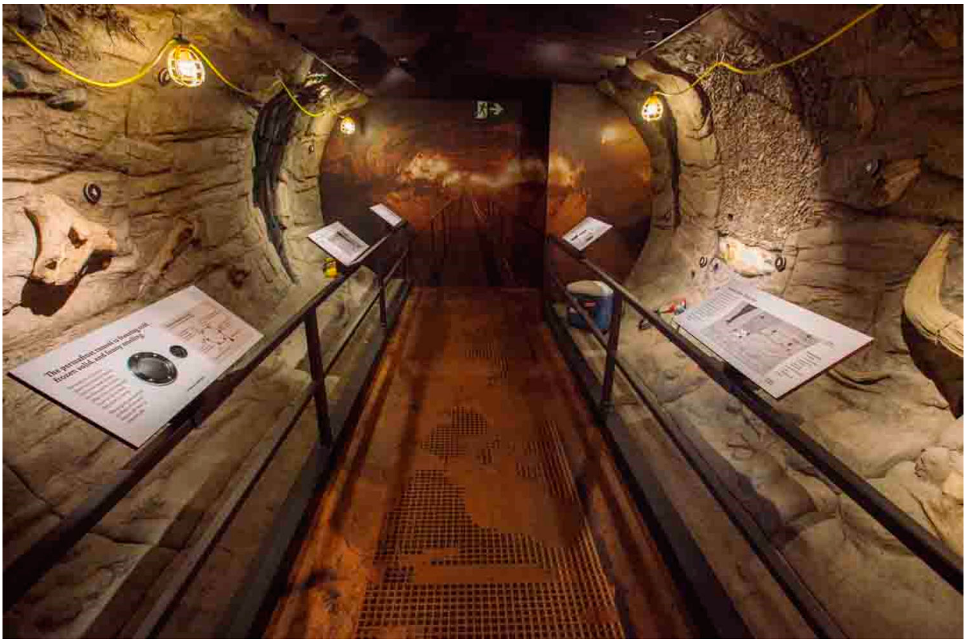

Figure 2. The replica tunnel at a science center in the lower 48 states. Photo credit: A. Woodard.

to illustrate the same points that were brought forth at the real tunnel. The researcher also referred to the replica tunnel as 'the tunnel' during the tours rather than explicitly comparing it to, or making references to, the tunnel in Alaska, saying, for example, 'you can see the mammoth tusk in the wall,' or 'the researchers' tools are here' in order to invoke the experience of being in the Alaskan tunnel.

Participants and recruitment

Families consisting of at least one adult and at least one child in the age range of 9–14 were asked to participate. Siblings could attend and were of variable ages. For tunnel visits in Alaska, we circulated flyers through local science teachers at three middle schools, offering a tour of the permafrost tunnel and soliciting involvement in the research project. At the science center location, we recruited through local science teachers at eight public and private middle schools. We registered 20 family groups for the tours (14 at the tunnel, 6 at the science center). Of these registrants, a total of 7 families at the tunnel and 5 families at the science center both participated in the tour and completed interviews with the researchers. Families ranged in size from 2 to 6 individuals. The total number of individuals in the study was 35. There was no cost to families to access the museum or the tunnel.

Data collection and analysis

This study took a comparative approach in answering our research questions. As described, we invited families to participate in tours at each of the two sites, and we conducted interviews with each family unit as a group following their visit. Interviews were semi-structured, consisted of 6–7 questions, and ranged from 10 to 30 min. The interview protocols were very similar at the two sites so as not to invoke differences in the responses from the questions. At the tunnel, families were interviewed after the tour. At the science center, we conducted these interviews immediately after the visitors experienced the replica tunnel itself, rather than after visiting the entirety of the exhibition, in order to make the best comparisons possible between the real tunnel in Alaska and the replica tunnel. Science center visitors were invited to view the rest of the exhibition at their leisure after the interview.

To analyze the interview data, first we employed content analysis, using a subset of codes that were previously developed and used by Allen (2002), and Zimmerman et al. (2015). We modified the original code definitions slightly, using 'perceptual' or 'conceptual' as our two coding categories (code definitions and examples appear in Table 1). Of note, the categories in the framework were originally developed in the context of coding observed family talk during a museum visit, rather than during family interviews. Although our context for applying these codes was different, the codes we used aligned well with our theoretical framework and thus served well as an analytical base for elucidating the nature of the learning.

We applied codes to the smallest excerpt that contained meaning. In some cases, family conversations during interviews contained more than one voice building on the same idea ('Dad: temperature. Boy: yeah, definitely temperature'), and in that case was included as a single excerpt. If individual or family voices diverged to introduce new ideas, rather than building on the same idea, these were counted as separate excerpts. A single code was applied to each excerpt. The authors independently applied the codes to a subset of interviews, then came together to discuss the coding. Dedoose software was used to code the data and to calculate inter-rater reliability ($k = 0.84$; generally, k above 0.80 is considered reliable).

Once data were coded as perceptual or conceptual, we used a chi-square analysis to look at the excerpt distribution across the sites ($N = 210$ excerpts). The null hypothesis was that the distribution of responses across the coding categories would be the same for the two sites. The alternative hypothesis was that there was enough difference in the distributions that we can say they are not equivalent.

Findings

We set out to consider the nature of learning in real vs. replicated environments. In order to get at this, we calculated the proportion of excerpts falling into each of our coding categories at each site (real tunnel or replica tunnel). We found that the distribution was different at the real tunnel than at the replica tunnel (Table 2). A chi-square test revealed that the observed proportions were different than the expected proportions (X^2 (1, $N = 210$) = 8.6, $p = 0.003$) across the two sites. The effect size was about halfway between small and medium (Phi = 0.20). As can be seen from Table 2, the category with the highest proportion of instances at the real tunnel was perceptual, while at the replica tunnel, the highest proportion was in the conceptual category. Below, we dig into each of these categories further, looking at what visitors discussed to make sense of their learning.

Perceptual

As mentioned above, the proportion of perceptual talk was higher at the real tunnel than at the replica tunnel. Notably, 66% of the interview talk was focused on the perceptual at the real tunnel, suggesting that sensory engagement was at the fore during the experience. With respect to these experiences, visitors mentioned activation of all senses, either in tandem or separately, including sight, smell, touch, sound, and even taste.

Table 1. Codes, definitions, and examples.

Code	Definition	Example
Perceptual	Visitor describes features or refers to sensory-based perceptions of the environment	'When I felt the ice, it felt sort of moist.'
Conceptual	Visitor describes a science concept	'The permafrost kept the tunnel, it's basically just dirty ice and it kept the tunnel from collapsing.'

Table 2. Proportions of perceptual vs. conceptual talk at the real vs. the replica tunnel.

Location	Perceptual talk	Conceptual talk
Real tunnel	66%	34%
Replica tunnel	42%	58%

At the real tunnel, a number of the sensory experiences mentioned were bound up in the representational aspect of the objects, rather than only in the physical qualities of the objects themselves. For instance, several people discussed how impactful it was that the fossils were still embedded in the original matrix. As one person put it:

> a lot of stuff in a museum is actual stuff that's been pulled from that location and set there, you don't actually get to *see where it came from* [emphasis added].

The perceptual experience of seeing objects *in situ* was memorable and valued by visitors apart from the attributes of the fossils themselves. The representational aspect of experience can also be seen in the exchange below:

> Dad: I got to taste it.
>
> Mom: twelve thousand year old … .
>
> Dad: Yeah, twelve thousand year old dirt.

Here, what stood out to the visitors was the idea of tasting something extremely old – 'I *got* to taste it' implies that this tasting was a privilege rather than an annoyance. The age of the dirt imbued it with a specialness that is likely not associated with tasting regular dirt.

Visitors also referred to specific sensory aspects of the real tunnel and the objects within the tunnel that stood alone from their representational aspects. People noticed the colors of the fossils and the ice, the 'powdered sugar' feel of the silt, the 'stinky cheese' smell of the tunnel, the cold temperature of the ice wedges and the ambient air, and the feeling of being in the hillside itself/within the earth. Visitors sometimes talked about how 'cool' or 'amazing' particular aspects of objects were to them, suggesting a link between affect and sensorial engagement. Previous work has also shown that there are tight connections between emotive responses and learning (Staus & Falk, 2017; Walker et al., 2013; Watson, 2015).

At the replica tunnel, there was also talk around the sensory aspects of objects themselves. However, the talk here differed in two ways: first, there was proportionally less perceptual talk at the replica than the real tunnel, as mentioned above, and secondly, many fewer senses were invoked. Specifically, sight and smell were the two primary senses people discussed during perceptual talk, with smell only mentioned if visitors had noticed and activated the smell station. Surprisingly, although the replica walls were made to be touched, touch was not mentioned during the instances of perceptual talk that we captured. Instead, visitors primarily focused on the look of the replica ice wedges, the replica bones, and the way the ground and the simulated dirt were laid out in the exhibit.

Conceptual

The proportion of the conceptual talk was proportionally lower at the real tunnel vs. the replica, but the nature of the talk was similar at the two sites. It was especially interesting to note that the kind of talk that emerged at each site was similar, as one may have expected that residents living in a location where permafrost occurs would be more familiar conceptually with permafrost. However, permafrost occurs underground and cannot normally be viewed. Concepts such as the structure of the ice wedges, the age of the permafrost, the fact that bones are embedded in the permafrost, and even the connection of permafrost to climate change, are rather specialized forms of knowledge that were included as part of the tour at both the replicated and real tunnel. In both places, the conceptual talk that emerged was directly related to the tour content and objects, sometimes perhaps drawing on more general prior knowledge about global warming.

In both places, the conceptual talk that emerged largely centered around ice wedges and fossilized bones. In particular, people discussed the ways in which permafrost, and especially ice wedges, were formed. They also discussed the age of the fossilized bones. In some cases, the conceptual ideas expressed reflected a sense-making process where the geophysical processes at play were reiterated or clarified:

> Mom: a crack with a huge, yeah a huge crack of ice in the middle of the ground, in the middle of a cave, that's, the water got down there and then it just froze, and stayed there
> Dad: instead of collapsing the entire tunnel
> Mom: exactly, or I don't know, the idea that also she said that as it gets cold that it like crunches down and compresses and how that leaves little gaps which just allows more water, that's just, what a crazy process.

In other cases, these conversations could be characterized more as synthesis explanations – visitors made connections between the formation and/or age of the permafrost and ice wedges and climate change:

> Boy: um, the ice in generalish made me think about global warming
> Interviewer: what were you thinking about?
> Boy: um it's crazy how the planet is getting warmer, it's melting all our ice, it's not good
> Mom: and how about …
> Dad: I was thinking about what she [tour guide] said about how this [the permafrost] isn't fossilized,
> Mom: yeah that
> Dad: that the material is just frozen so when it melts it's going to rot
> Mom: and release gas, it's going to increase.

For many of the conceptual conversations, including the one above, it was clear that visitors drew on the information conveyed during the tour during their conversations. However, in many cases the objects, whether real or replicated, also played an integral role in the concept being expressed. For example, one visitor expressed: 'The bones that were in there show us a little bit of the anatomy of animals that were alive in the past … .' In many cases, the conceptual talk was paired with perceptual talk, and appeared to prompt the reflection that went along with it. For instance, immediately following a perceptual observation about the bones was this conceptual observation:

> You know, we kind of forget this land was inhabited before us … like why aren't mammoths, you know, still living here?

Discussion and implications

We saw clear differences in the observed, versus expected, proportions of talk at the two sites. Specifically, the highest proportion of talk instances at the real tunnel was perceptual, while at the replica tunnel, the highest proportion was in the conceptual category. Looking across both the proportion and the nature of talk in both the perceptual and conceptual categories, our results suggest that the rich sensory environment was foremost in the minds of the visitors to the real tunnel, influencing the nature of their experience. The prevalence of talk around all of the senses, as well as the sense of being immersed in a real environment, illustrates the high level of sensory engagement present at the tunnel. In contrast, people at the replicated tunnel mostly mentioned sight as the primary form of sensory engagement, and usually mentioned seeing specific objects embedded in the replica tunnel, rather than feeling immersed in the setting. We suggest that a 'sensory pluralism' was at play (Fulkerson, 2014) at the real tunnel, in which the experience at the tunnel went beyond the perceptions of the individual senses to create a feeling that is difficult to replicate by designing for only a few of the senses. Sight, smell, touch, sound, and taste, including features such as the ambient temperature, all played a role in the tunnel experience, and seemed to create a whole that was greater than the sum of its parts.

Considering these findings, a question arises about whether the high level of sensory stimuli could, in fact, have a blocking effect in terms of conceptual learning. In a study of school-aged children on a museum field trip, Falk et al. (1978) found that novel, stimulus-rich experiences actually interfered with conceptual learning, in part through producing an 'exploratory drive' that caused students to attend more to novel stimuli. Thus, it is possible that the lower proportion of conceptual explanations at the real tunnel, as opposed to the replica tunnel, resulted from visitors attending so strongly to the novel, stimulus-rich environment of the tunnel to the degree that less conceptual learning occurred.

However, we postulate that this is not necessarily the case for two reasons: First, the nature of the conceptual talk was similar at both sites, even though the prevalence was lower at the tunnel. In both cases, complex sense-making processes were observed, suggesting that the blocking effect was not necessarily at play. Secondly, much of the conceptual talk at both places built on objects as 'nodes' (Leinhardt & Crowley, 2002) that resulted in reflective talk about conceptual knowledge conveyed during the tour. It is interesting to note that this occurred regardless of whether the object was real or replicated. Therefore, we suggest that sensorial engagement did not come at the expense of conceptual learning.

Our results imply that the choice to employ real or replicated objects in exhibitions matters for visitor learning in some ways, but perhaps not in others. What was learned conceptually in our study was similar across real and replicated objects. Visitors clarified, reiterated, and synthesized concepts that were taken up through interacting with objects, both real and replicated, in similar ways. However, visitor learning is not limited to the conceptual. There were affordances of perceptual exploration that went beyond the conceptual: the immersive nature of the real tunnel was memorable, valued by visitors, and allowed them to understand the environment through the senses rather than only through the intellect – that is, a sensorial understanding of the experience – and this sensorial aspect was more prominent in the 'real' setting. Given these findings, exhibition designers should think carefully about the goals of specific exhibit elements and privilege real objects and immersive experiences accordingly.

Our study does have some limitations. In particular, the findings are based on a relatively small number of visitor groups, and thus the study should be viewed as exploratory. There is rarely the opportunity to compare visitor engagement at an entire replicated setting with an entire real setting upon which that replicated setting is based. Thus, our study offers important insights that may be difficult to get at in other ways. Still, future research could dive into this area more deeply by looking at proportions of conceptual vs. perceptual talk around real vs. replicated objects within a single museum setting.

Conclusion

Research has previously shown that visitor's interpretations of objects are not static and predictable, but instead arise from an interaction of the prior knowledge and world view of the visitor, the characteristics of the object, and the context in which the object is experienced (Falk & Dierking, 1992). However, relatively little is known about what is taken up in real vs. replicated settings. This study suggests that visitor learning is impacted by the rich sensory environment associated with real settings – in particular, visitors appeared to be sensorially engaged by real objects and the real setting more than by replicated objects and the replicated setting, while the nature of concepts taken up was similar across both types of settings. Our study adds to the small but growing literature about how real and replicated objects impact visitor learning.

Acknowledgements

We thank the other project leads, Matthew Sturm and Vicki Coats, and the entire exhibition team at OMSI and UAF for rich discussions about real and replicated objects and experiences. We particularly thank Margaret Rudolph for leading the tours for this study. We also wish to thank the study participants for their time. Finally, two anonymous reviewers supplied comments that greatly improved the manuscript. This work was supported by the National Science Foundation under Grant NSF-DRL 1423550. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the National Science Foundation under Grant NSF-DRL 1423550.

ORCID

Laura D. Carsten Conner http://orcid.org/0000-0002-8457-6837
Suzanne M. Perin http://orcid.org/0000-0001-6463-6217

References

Allen, S. (2002). Looking for learning in visitor talk: A methodological exploration. In G. Leinhardt, K. Crowley, & K. Knutson (Eds.), *Learning conversations in museums* (pp. 265–309). Erlbaum.

Bunce, L. (2016). Appreciation of authenticity promotes curiosity: Implications for object-based learning in museums. *Journal of Museum Education*, *41*(3), 230–239. https://doi.org/10.1080/10598650.2016.1193312

Cox-Petersen, A., Marsh, D., Kisiel, J., & Melber, L. (2003). Investigation of guided school tours, student learning, and science reform recommendations at a museum of natural history. *Journal of Research in Science Teaching*, *40*(2), 200–218. https://doi.org/10.1002/tea.10072

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science*, *323*(5910), 66–69. https://doi.org/10.1126/science.1167311

Dudley, S. H. (2012). Encountering a Chinese horse: Engaging with the thingness of things. In S. H. Dudley (Ed.), *Museum objects: Experiencing the properties of things* (pp. 28–42). Routledge.

Eberbach, C., & Crowley, K. (2005). From living to virtual: Learning from museum objects. *Curator: The Museum Journal*, *48*(3), 317–338. https://doi.org/10.1111/j.2151-6952.2005.tb00175.x

Ellenbogen, K., Luke, J. J., & Dierking, L. D. (2007). Family learning in museums: Perspectives on a decade of research. In J. H. Falk, L. D. Dierking, & S. Foutz (Eds.), *In principle, in practice: Museums as learning institutions* (pp. 17–30). AltaMira.

Evans, E. M., Mull, M. S., & Poling, D. A. (2002). The authentic object? A child's-eye view. In S. G. Paris (Ed.), *Perspectives on object-centered learning in museums* (pp. 50–71). Erlbaum.

Falk, J., & Dierking, L. (1992). *The museum experience*. Whalesback Books.

Falk, J. H., & Dierking, L. D. (2000). *Learning from museums: Visitor experiences and the making of meaning*. AltaMira.

Falk, J. H., & Dierking, L. D. (2012). *The museum experience revisited*. Left Coast.

Falk, J. H., Martin, W. W., & Balling, J. D. (1978). The novel field-trip phenomenon: Adjustment to novel settings interferes with task learning. *Journal of Research in Science Teaching*, *15*(2), 127–134. https://doi.org/10.1002/tea.3660150207

Falk, J., & Storksdieck, M. (2005). Using the contextual model of learning to understand visitor learning from a science center exhibition. *Science Education*, *89*(5), 744–778. https://doi.org/10.1002/sce.20078

Fulkerson, M. (2014). Rethinking the senses and their interactions: The case for sensory pluralism. *Frontiers in Psychology*, *5*, 1426. https://doi.org/10.3389/fpsyg.2014.01426

Gurian, E. H. (1999). What is the object of this exercise? A meandering exploration of the many meanings of objects in museums. *Daedalus*, *128*(3), 163–183.

Hampp, C., & Schwan, S. (2014). Perception and evaluation of authentic objects: Findings from a visitor study. *Museum Management and Curatorship*, *29*(4), 349–367. https://doi.org/10.1080/09647775.2014.938416

Hampp, C., & Schwan, S. (2015). The role of authentic objects in museums of the history of science and technology: Findings from a visitor study. *International Journal of Science Education, Part B*, *5*(2), 161–181. https://doi.org/10.1080/21548455.2013.875238
Hein, G. (1998). *Learning in museums*. Routledge.
Jant, E. A., Haden, C. A., Uttal, D. H., & Babcock, E. (2014). Conversation and object manipulation influence children's learning in a museum. *Child Development*, *85*(5), 2029–2045. https://doi.org/10.1111/cdev.12252
Klahr, D., Triona, L. M., & Williams, C. (2007). Hands on what? The relative effectiveness of physical versus virtual materials in an engineering design project by middle school children. *Journal of Research in Science Teaching*, *44*(1), 183–203. https://doi.org/10.1002/tea.20152
Leinhardt, G., & Crowley, K. (2002). Objects of learning, objects of talk: Changing minds in museums. In S. G. Paris (Ed.), *Perspectives on object-centered learning in museums* (pp. 301–324). Erlbaum.
Soren, B. J. (2009). Museum experiences that change visitors. *Museum Management and Curatorship*, *24*(3), 233–251. https://doi.org/10.1080/09647770903073060
Staus, N. L., & Falk, J. H. (2017). The role of emotion in informal science learning: Testing an exploratory model. *Mind, Brain, and Education*, *11*(2), 45–53. https://doi.org/10.1111/mbe.12139
van Gerven, D., Land-Zandstra, A., & Damsma, W. (2018). Authenticity matters: Children look beyond appearances in their appreciation of museum objects. *International Journal of Science Education, Part B*, *8*(4), 325–339. https://doi.org/10.1080/21548455.2018.1497218
Vygotsky, L. S. (1978). *Mind in society* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Harvard University Press.
Walker, G. J., Stocklmayer, S. M., & Grant, W. J. (2013). Science theatre: Changing South African students' intended behaviour towards HIV AIDS. *International Journal of Science Education, Part B*, *3*(2), 101–120. https://doi.org/10.1080/09500693.2011.633939
Watson, S. (2015). Emotions in the history museum. In S. Macdonald & H. Rees (Eds.), *The international handbooks of museum studies* (pp. 283–301). Wiley.
Wehner, K., & Sear, M. (2010). Engaging the material world: Object knowledge and *Australian Journeys*. In S. Dudley (Ed.), *Museum materialities: Objects, engagements, interpretations* (pp. 143–161). Routledge.
Zimmerman, H. T., Land, S. M., McClain, L. R., Mohney, M. R., Choi, G. W., & Salman, F. H. (2015). Tree Investigators: Supporting families' scientific talk in an arboretum with mobile computers. *International Journal of Science Education, Part B: Communication and Public Engagement*, *5*(1), 44–67. https://doi.org/10.1080/21548455.2013.832437