Scaffolding a Science Museum Exhibit through Signage

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Abstract: Scaffolding learning in science museum exhibits can be a challenging endeavor. Learning in these settings is self-directed, sporadic, and lacking in structure (Falk, Dierking & Semmel, 2013). Museum educators and exhibit designers struggle to provide the appropriate types and amounts of scaffolding, where too little scaffolding can result in suboptimal learning outcomes while too much scaffolding can result in an "over-formalization" of the exhibit (Yoon et al., 2013). This study examines the use of signage in scaffolding students' engagement with a science exhibit about light. Twelve students were asked to engage in four activities within the exhibit. Videos of student behavior were recorded and thematically coded. Findings indicate that textual scaffolds, as they were implemented in this exhibit, may have missed opportunities to promote meaningful engagement with exhibit activities. Implications for exhibit design practice and research are discussed.

Keywords: Science exhibit, science museum, scaffold, engagement

Introduction

Visits to science museums are frequently described as memorable and engaging (Falk & Dierking, 1992). However, because visitor behavior at science museums is largely self-directed, sporadic, and lacking in structure, researchers and educators have struggled to define and contextualize what it means to learn in these spaces (DeWitt & Storksdieck, 2008; Falk, Dierking & Semmel, 2013). Consequently, research on science museums offers little in the way of best practices for how to support learning through engagement with exhibits. Providing the appropriate types and amounts of scaffolding can thus prove to be a challenging task for museum educators and exhibit designers. Some studies have suggested that too little scaffolding can result in suboptimal learning outcomes while too much scaffolding can result in an "over-formalization" of the exhibit (Yoon et al., 2012; Yoon et al., 2013).

Science museum exhibits can be scaffolded in a variety of ways. Tissenbaum (2018) categorize the scaffoldings in museums in two ways: social scaffolds and material scaffolds. Social scaffolds facilitate the interactions between family members, museum staff, and peers. Material scaffolds, such as objectives, text, representations, activities, and technologies, help visitors to understand new concepts, relationships, or practices. Material scaffolds may come in digital or text-based forms (Yoon et al., 2018). Textual scaffolds, such as exhibit labels and other signage, have been shown to affect the ways in which visitors interact with exhibit components and with one another (Atkins et al., 2009; Wolf & Wood, 2012). Yoon et al. (2018) highlight some important affordances of textual scaffolds, including providing instructions for activities, asking questions, and encouraging visitors to evaluate their understanding. In this study, we examine the textual scaffolds of a science museum exhibit on light. We address the following research questions: *1) What types of supports do informational exhibit signs provide?; 2) How do middle school students engage with informational signs at a science exhibit?*; and *3) To what extent and in what ways are students' engagement with signs and their engagement with the exhibit related* ?

Conceptual Frameworks

In educational research, much has been said about the benefits of promoting student engagement with science. However, engagement is a complex and multifaceted construct which has been defined in a number of different ways. In this study, we operationalize the construct of engagement according to the definition put forth by Sinatra et al. (2015). Sinatra et al. (2015) identify four categories of engagement: behavioral engagement, emotional engagement, cognitive engagement, and agentic engagement. Only the first two categories, behavioral and emotional, are analyzed here.

Behavioral engagement is the observable act of students being involved in learning. Behavioral engagement typically refers to the actions students take while involved in learning activities. In this study, our observations of students' behavioral engagement focused on whether or not they read exhibit signage, how substantive their manipulations of exhibit components were, and the extent to which they engaged in science-related behaviors such as hypothesis-formation and sense-making.

Emotional engagement is defined as students' emotional reactions to academic subject areas such as science. Emotional engagementinvolves interest, boredom, happiness, anxiety, and other affective states, any of which could affect learners' involvement with learning or their sustained effort in completing the tasks. To observe and categorize student affect, we employed a circumplex model of emotional engagement originally developed by Bartett & Russell (1998) and later adapted by Linnenbrink-Garcia, Patall, & Pekrum (2016). This model takes into account student valence, which can be positive or negative as well as their level of activation, which can be high or low of the individual (See Figure 1).

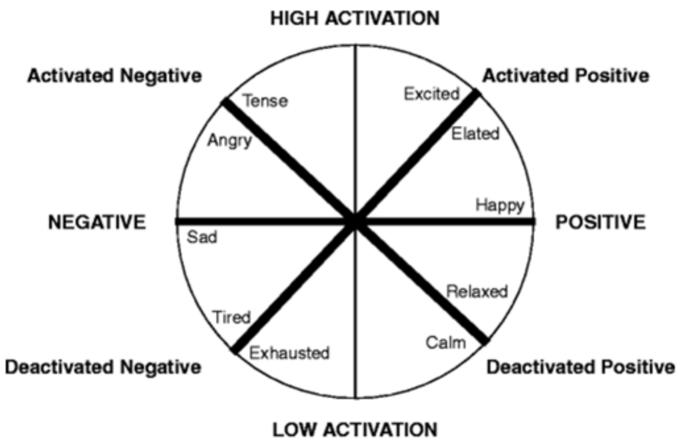

Figure 1. *Student Affective Valences - Linnenbrink-Garcia, L., Patall, E. A., & Pekrun, R. (2016)*

Methodology

Study Context. The study was conducted in the southeastern United States at two sites, a science museum and planetarium where the exhibit is permanently housed and a science summer camp at a rural school, where the exhibit was installed temporarily. The exhibit, entitled Hidden No More, is comprised of multiple activities which highlight the discoveries of scientists from underrepresented groups. In the current phase of the exhibit – phase 1 of 3 – visitors explore the properties of light and applications of optics reflecting the work of two scientists, one historical and one contemporary. There are multiple components within the exhibit which include hands-on activities, animations, a photo booth, and virtual reality. This study focuses on the hands-on inquiry components and their corresponding signage. Table 1 contains a brief description of the four hands-on activities that comprise the focus of this study.

Activity	Description
Blending Beams	Turn the knobs to turn on different colors of light and explore what happens when mixing the colors of light.
Changing Color	Press differently-colored buttons to shine colored light on Lego blocks.
Filtering Color	Place each color filter over the pictures of shapes and nebulae and explore how the color of picture changes.
Studying Spectra	Place a molecule strip on top of the spectrum to match missing wavelength lines.

Table 1. *Descriptions of exhibit activities.*

Participants. This study included 12 participants between 6th and 8th grade (see Table 2). The overall demographics of the study reflect the racial and ethnic composition of the communities where the exhibit is installed. Every participant in this study engaged with all the exhibit components of *Hidden No More.*

Race		Gender		Grade Level	
Black	15.3%	Female	46.2%	6th	14.6%
Hispanic/Latino	15.3%	Male	53.8%	7th	23.1%
White	53.8%			8th	53.8%
Asian	7.7%			Not Reported	7.3%
Not Reported	7.7%				

Table 2. *Participant Demographics (n=12)*

Data Collection and Analysis. Two phases of data collection and analysis were conducted. To answer the first research question, exhibit signs were analyzed to determine the types of scaffolding they provided. Each activity in the exhibit was scaffolded by a single corresponding sign. Signs were coded deductively based on the findings of Yoon et al. (2018), who identified five affordances of textual scaffolds in informal learning settings (Table 3). For each sign, affordances were coded as present or absent.

Affordance of Scaffold	Description
Instructions	Provides information about how to complete tasks
Connecting Questions	Enables connections between ideas and deeper level engagement with ideas
Metacognitive Directions	Enables evaluation of one's own understanding
Strategic Cues	Promotes generation of new ideas
Focus Supports	Helps to develop understanding of the problem or overarching goal

Table 3. *Affordances of Textual Scaffolds (Yoon et al., 2018)*

To investigate the second and third research questions, videos of students' engagement with the exhibit components were recorded using point-of-view cameras. Videos were transcribed and thematically coded via a combination of *a priori* and emergent coding strategies. *A priori* coding focused on whether or not students read the textual scaffolds, how long students persisted with activities, how substantive students' manipulations of the exhibit components were, what students said while interacting with the exhibit, and students' observable affects while interacting with the exhibit.

Three emergent codes were developed to describe the nature of students' manipulations of the activities. Cursory manipulations occurred when students engaged in brief and/or low-effort interactions with exhibit components. Substantive manipulations occurred when students engagement reflected effort with exhibit components that was sustained. Unintended manipulations occurred when students manipulated exhibit components in ways that were not intended by the exhibit designers. Emergent codes were also developed to capture the nature of students' conversations. Specific attention was paid to scientific talk such as hypothesis-formation, observations of scientific phenomena, and sense-making.

The Linnenbrink-Garcia et al. (2016) circumplex model was used to deductively code student affect. Under this model, student affect may be characterized in terms of valence, or how positive or negative their observable feelings were, and activation, or how animated they were in expressing or mobilizing those feelings. A *positive, activated* state, for example, indicates that a student was visibly excited while engaging with an exhibit component while a *positive, deactivated* state indicates that a student was mildly amused. Conversely, a *negative, activated* state indicates that a student was visibly angered or frustrated by an exhibit component while a *negative, deactivated* state indicates that a student was bored or confused by an exhibit component. All videos and transcripts were first coded by individual members of the research team. The team then met on a regular basis to establish full intercoder agreement.

Results

Initial analyses of the data indicate that textual scaffolds often missed opportunities to support students' meaningful engagement with the exhibit components. In fact, when students approached the activities within the exhibit, they were more likely to ignore the corresponding signage (69.6% of the time) than they were to read it (30.4%). Only one of the twelve students was observed reading the signs at all four activities. In general, students seemed to prefer to begin the activities with their own hands-on manipulation (e.g. turning knobs or pressing buttons). This pattern is consistent with previous findings on visitor behavior in informal museum settings (see Falk, Dierking, & Semmel, 2013). However, students' self-guided manipulations tended to be cursory – rather than substantive – in nature. The level of cognitive and affective engagement from students was lower than expected, and very little evidence of scientific talk was observed among the students. Included below are the results from the initial sign analysis and the findings from each of the four exhibit activities.

Sign Analysis

To investigate the first research question, exhibit signs were analyzed using the Yoon et al. (2018) framework to identify the types of scaffolding they provided. Yoon and colleagues (2018) identified five affordances of textual scaffolds (see Table 3). Four of these affordances – instructions, connecting questions, strategic cues and focus supports – were found to be present on all exhibit signs in this study. In addition, each sign contained graphics which were intended to bolster students' understanding of the relevant scientific concepts. What emerged was that the signs did not contain the scaffold identified as metacognitive direction. Through analysis, all signs were were formatted in such a way that focus supports (e.g. background information) were presented first, followed by instructions for the corresponding activities, with connecting questions and strategic cues located towards the bottom (see Figure 2).

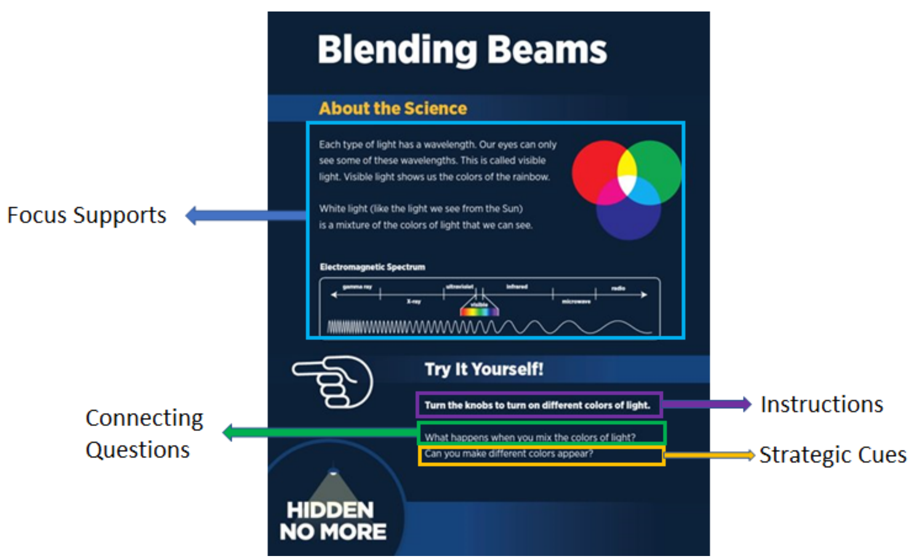

Figure 2. *Exhibit Sign Coded for Scaffolding Affordances.*

Activity 1 – Blending Beams

The Blending Beams activity was designed to allow visitors to mix different colors of light by turning knobs on a machine and observing the effects. The signage for the activity provides background information about wavelengths of light, instructions for the activity, two guiding questions, and two graphic knowledge supports. Notably, students were more likely to begin this activity by manipulating the knobs (55.6%) than by reading the signage (44.4%). In the example below, a student approaches the exhibit activity and immediately engages with the components:

> *Yeah. I did this before. (moving the filter in front of the beam). Like something like this, right? Yeah, it's like this or something?????*

Here, while the student is focused and engaged, they are manipulating the exhibit components in unintended and unproductive ways. The filter in their hand is intended for a different activity and serves no purpose for Blending Beams. Without the appropriate scaffolding, this student's engagement with Blending Beams results in confusion. In another example, a student reads the sign but becomes confused by the scientific terminology. As in the previous example, the student's confusion leads to unproductive manipulations of the exhibit components.

> *….(reading the sign) Each type of light has a wavelength. What is...I don't know what wavelength is.....(continues reading)….Our eyes can only see some of these wavelengths. Look. Wait wait wait. It says turn the knobs to show different colors of light?*

Affective engagement at this activity was low compared to other activities within the exhibit. Only 16.7% of observations of student affect were coded as *positive, activated*. *Negative, deactivated* affects were coded with the same frequency (16.7%). In other words, students were just as likely to be confused by the activity as they were to be excited about it. Students' affective engagement with this activity was overwhelmingly coded as *positive, deactivated* (66.7%). This indicates that most students seemed to be amused by the activity, but otherwise demonstrated no strong reactions to it.

Figure 3. *Blending Beams.*

Similarly, behavioral engagement was low. Students did not spend much time mixing the colors of light. Only 33.3% of students' engagement behaviors with the activity were coded as substantive. The rest were coded as cursory manipulations (44.4%), unintended manipulations (11.1%), or no manipulation at all (11.1%). Furthermore, there was no evidence of students talking about science content while engaging with the activity. Only one student mentioned the word "wavelength" while engaging with the activity, and that was only to admit that she did not know what the term meant.

Activity 2 – Filtering Color

In the Filtering Color activity, students look at various images through differently-colored filters to observe how the images change. The signage for the activity provides background information about absorption and reflection of light, instructions for the activity, one guiding question, and a graphic knowledge support. Students were more likely to begin this activity by manipulating the filters (76%) than by reading the signage (24%).

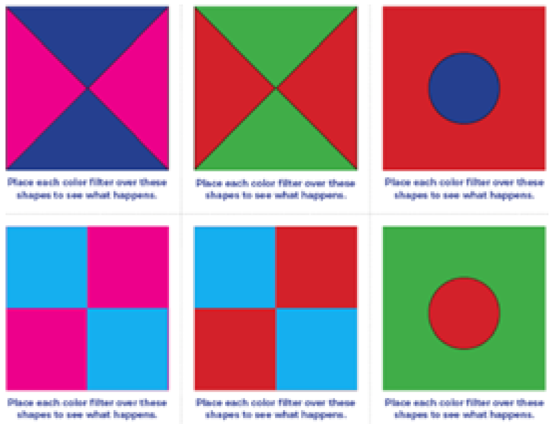

Figure 4. *Filtering Color.*

Affective engagement at this activity was high. A vast majority of observations of students' affects were coded as positive, with *positive, activated* codes accounting for 56% of the observations and *positive, deactivated* codes accounting for 40%. This indicates that students had positive feelings about the activity and that those feelings were generally more activated in this activity than in Blending Beams.

Additionally, students' behavioral engagement was observed to be more substantive in this activity. Substantive manipulations of the activity accounted for 48% of all student behavior. The remaining behaviors were coded as cursory manipulations (28%), unintended manipulations (16%), or no manipulations at all (8%). However, students did not talk about any relevant scientific concepts such as wavelength, absorption, or reflection while engaged with this activity. In the following example, a student is enjoying the activity but does not seem to further their understanding of the relevant science:

> *This is pretty cool. I feel like I can see this clearest with the orange [filter] and this clearest with the yellow [filter]. But it's weird...I can see this one best with the blue [filter]. Yeah that's kind of cool.*

This student, like most of the students who engaged with the Filtering Color activity, chose to explore the activity's components without reading the signage. Still, they were able to figure out that they were supposed to examine the various images and shapes by using the differently-colored filters. This suggests that the instructional prompts may have been unnecessary for this particular activity. However, the student's verbalizations indicate some confusion about the scientific principles underlying the activity. It is not clear what the student means by seeing one image "clearest" with the orange filter and another image "best" with the blue filter. As indicated on the Filtering Color signage, the filters only allow light of the corresponding color to pass through, absorbing all other colors. The colors of the images and shapes thus seem to change when different filters are applied. If the student had been equipped with this information, they may have been better able to contextualize their observations.

Activity 3 – Changing Color

In the Changing Color activity, students press buttons to shine differently-colored lights on Lego blocks to observe how the blocks appear to change color. As with the Filtering Color activity, this activity is designed to allow visitors to explore the concepts of absorption, reflection, and wavelengths. The signage for this activity provides background information about absorption and reflection, instructions for the activity, a guiding question, strategic cues, and a graphic knowledge support. Upon approaching this activity, however, students only appeared to read the signage 23.8% of the time.

Students almost universally demonstrated positive affects while engaging with the Changing Color activity (95.2%). *Positive, activated* affects accounted for 66.7% of observations while *positive, deactivated* affects account for 28.6%. In other words, students were generally excited – or at the very least amused – by the activity. Only one student expressed confusion about the purpose of the activity.

Behavioral engagement, however, rarely resulted substantive manipulations with the activity. Unintended manipulations, such as instances where students pressed the buttons as rapidly as possible, occurred in 47.6% of observations. Cursory manipulations, such as when students pressed a button or two and then moved to a different activity, accounted for 38% of observations. Only 14.3% of the time did students spend time observing the effects of differently-colored lights. Scientific talk was

Figure 5. *Changing Color.*

again largely absent from students' conversations, with no explicit mentions of scientific terminology like "absorb", "reflect", and "wavelength" and few attempts to make sense of the activity. In the following example, four students approach the Changing Color activity together without reading the signage.

Mika: What's this?
Callum: It's like different color lights on the Legos.
Mika: Wait I wanna see...I wanna see something.
Logan: Ok let's all press a button and go at the same time.
Andre: Yeah, because there's four of us.
Callum: Ok. Three...two...one... [all four students start mashing buttons as rapidly as they can]

These students, while seemingly engaged on an affective level, spent very little time observing, testing, or discussing the underlying scientific principles at play in this activity. Instead of methodically testing out the effects of each button, they elected to press all of the buttons rapidly and simultaneously. Without structure or guidance, student learning was limited. While the signage for Changing Color does provide connecting questions and prompts (e.g. "What happens to the Legos under different colors of light?"), this information is located at the bottom of the sign underneath other textual and graphic information. These questions may serve students better by being more prominent on the activity's signage.

Activity 4 – Studying Spectra

The Studying Spectra activity is designed to allow visitors to learn how spectroscopy techniques are used to explore the elemental compositions of exoplanets. In this activity, visitors play a simple matching game to pair molecule filters with a corresponding set of exoplanet profiles to determine which exoplanets contain the elements necessary for life. The signage for this activity contains focus supports and background information about spectra, instructions for the activity, a guiding question, and a graphic knowledge support. In only 31.3% of observations, however, did students spend time reading the signage.

Affective engagement at Studying Spectra was the lowest for all four activities. *Positive, activated* affects were observed only 18.8% of the time. *Positive, deactivated* affects accounted for 56.3% of observations. *Negative, deactivated* affects such as confusion were observed in 25% of cases. In other words, while most students demonstrated positive affects while engaging with the activity, these affects were not highly activated. In fact, students were more likely to be confused by the activity than excited by it.

Unsurprisingly, behavioral engagement was also low. Only 25% of students' manipulations of the activity were substantive in nature. Cursory manipulations accounted for 12.5% of students' behaviors while unintended manipulations accounted for 18.8%. Students opted out of the activity altogether 43.8% of the time. Furthermore, students had no discussions about spectroscopy and made few attempts to understand the underlying purpose of the activity. In the following example, three students approach the Studying Spectra activity without reading the sign:

Cara: Is this what stuff looks like? Eh I don't get this. What does this one do?
Joshua: What's that?
Cara: Not sure.
Carmen: What does it say?
Joshua: [grabbing the molecule filter] I think you put it up here.
Cara: I guess you put it up here.

Upon approaching the activity, the three students express confusion about the activity's purpose. When they initially struggle to place the molecule filters in the correct locations, Carmen asks about the signage. Rather than taking time to read the sign, however, the students prefer to figure the activity out on their own. Eventually, they are successful in placing the molecule filters but do so without discussing any of the relevant scientific concepts. Without the appropriate scaffolding to help contextualize student learning, this activity may have missed opportunities to help students deepen their understanding of science.

Discussion

The textual scaffolds analyzed in this study were designed to provide important background content knowledge, instructions, and connecting questions for a science museum exhibit on light. This analysis suggests that the textual scaffolds – in the form of exhibit signage – may fall short of these goals. Students seem to be more likely to ignore signage than to read it. Furthermore, reading the signs seemed to have little association with higher levels of engagement or science talk.

So why might these textual scaffolds fail to achieve their goals, and how might they be improved? According to Yoon et al. (2013), they found that too much scaffolding in museums tended to result in an "over-formalization" of exhibits and a reduction in informal behaviors such as experimentation and question-generation. In the case of this exhibit, one hypothesis might suggest that the signage contains too much text, or a sub-optimal arrangement of the text. Currently, the signage in the exhibit is formatted such that the background information is presented first, followed by instructions for the corresponding activity, and ending with questions for visitors to answer as they engage with the activity. An alternative format might first include connecting questions or strategic cues which encourage students to explore and experiment with exhibit components prior to reading any background information. In other words, the alternative format would prioritize informal participation behaviors over more structured ones. By engaging with the activities first, students may be better equipped to contextualize any feedback or background information they receive later.

Consider the example in Figure 6. The redesigned signage prominently displays connecting questions and strategic cues in large font. Immediately below the guiding questions are instructions that prompt visitors to begin the activity. By formatting the sign in this way, a potential reframing of the activity may occur such that exploration and experimentation are prioritized. This differs from the exhibit's current signage which places focus supports first. In the redesigned format, focus supports are presented after visitors have engaged in exploration and experimentation.

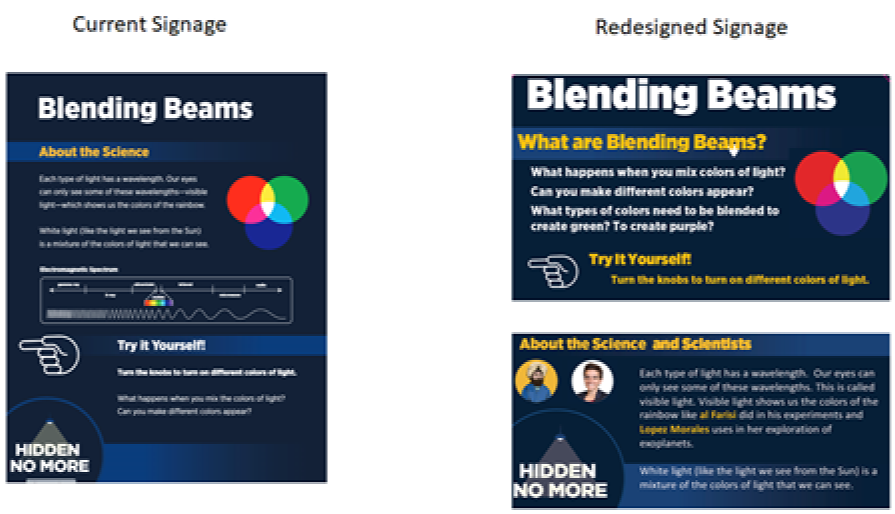

Figure 6. *Comparison of Current Signage and Redesigned Signage.*

As Atkins et al. (2009) demonstrate, the presence and types of exhibit labels impact the ways in which visitors frame their activities. Atkins et al. also offer a word of caution: As with other elements of exhibit design, the design of exhibit labels and signs involves a number of tradeoffs. Choices made about exhibit signage may have unintended effects on visitor behaviors and outcomes. It is not the case, then, that one exhibit sign is necessarily "better" than another, only that different signs provide different frames for exhibit activities. Furthermore, because museum activities often differ from one another, they require different amounts and types of scaffolding. There is no one-size-fits-all solution to the dilemma of exhibit signage.

In addition to informing museum signage practices, this study may also serve as a foundation for future research on exhibit design. It is important to note that the findings discussed here are associative in nature and represent only the first steps toward understanding the effects of scaffolding in science museum exhibits. With a larger sample size, a pre/post study design, and a larger variety of scaffolds, future studies may be better situated to uncover any causal links between exhibit scaffolds and visitor engagement.

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