Formal Lessons Improve Informal Educational Experiences: The Influence of Prior Knowledge on Student Engagement

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ABSTRACT
Educational experiences can be influenced by novel experiences, yet educators often overlook the influence novelty exerts on students. This quasi-experimental study manipulated prior knowledge before a zoo field trip for 210 urban 7th-grade students from 2 schools, 1 comprised mostly of low-socioeconomic status (SES) families and 1 comprised mostly of middle-SES families. Students participated in 1 of 2 preparatory lessons, only 1 of which previewed field trip-related content, thereby increasing prior knowledge for half the students from each school. Prior knowledge significantly increased learner engagement, measured through attentiveness, from both schools, but in different types of behaviors. Students from the low-SES school demonstrated more attentiveness if their preparatory lesson previewed field trip material than if it was unrelated to the field trip. Students from the middle SES school displayed the same level of attentiveness in both conditions (and overall higher than the low-SES students). This study highlights complexities associated with prior knowledge and reveals strategies to help improve engagement levels for students visiting informal learning environments.

Educational research in informal learning centers, such as zoos and museums, reveals best practices to integrate informal education strategies with formal education, and field trip research demonstrates content knowledge gains after informal learning experiences (see the literature review by DeWitt & Storksdieck, 2008). The current study uses the novel approach of measuring student engagement through attentiveness on site at an informal learning setting, while considering background factors that may influence the learning process and outcomes. Specifically, prior knowledge was manipulated, and student attentiveness was measured while school groups visited an interactive, neuroscience-themed exhibit at a local zoo.

The Committee on a Conceptual Framework for New Science Education Standards emphasized the importance of ensuring that students have an appreciation of the wonder of science and that they are able to continue to learn about science outside of school settings (National Research Council, 2012). Indeed, research demonstrates that new learning experiences may have motivational impacts. Palmer’s (2009) research suggests that the novelty of a learning experience was the greatest single driver behind students’ interest in learning. Moreover, the incorporation of informal science learning opportunities into the formal science curriculum may help bridge the conceptual gap between real-world experiences...
and classroom activities (Melber & Abraham, 2002; National Research Council, 1996). Methods to maximize learning outcomes from informal education are therefore of great interest in the scientific community.

Cognitive learning gains from informal experiences continue beyond the informal learning experience, as students investigate and discuss related content back in school or at home (Randler, Baumgartner, Eisele, & Kienzle, 2007). Thus, research suggests informal science educators can enhance science literacy, improve motivation, and maximize learning for their students. Yet, methods that will maximize student learning outcomes in such settings require further study. Because zoos and aquariums host over 175 million yearly visitors (Association of Zoos and Aquariums, 2014), including school groups, they provide prime opportunities to educate the public as well as school children. With the reach and popularity of school field trips to venues such as zoos, greater access to education research might further guide and validate the methods and missions of informal learning centers (Falk, 1983; Luebke & Grajal, 2011; Moss & Esson, 2013).

**Cognitive learning and prior knowledge**

Learning is an accommodating process in which the learner actively builds upon existing cognitive frameworks and constructs new meanings related to prior knowledge (Osborne & Wittrock, 1989). For formal and informal educators alike, student (or visitor) characteristics must be taken into account when planning for students to carry out assignments, participate in lessons, and engage with exhibits. One important student or visitor characteristic is prior familiarity with the content material and the learning environment. Reviews of research on learning at informal institutions indicate that visitors enter these facilities with a wide range of preexisting knowledge, experiences, and interests (Falk, 2009; Falk, Heimlich, & Bronnenkant, 2008; Stein & Storksdieck, 2008). This variability directly influences what is learned and how information is processed in these settings (Falk & Adelman, 2003; Falk & Dierking, 2000). Moreover, although prior research findings on effects of group size on behavior, content recall, and motivational outcomes are conflicting, the size and composition of the group in the learning environment may influence learning and engagement (Kirchgessner & Sewall, 2015; Stern, Powell, & Ardoin, 2008).

Furthermore, prior experiences and understanding have an impact on how one visitor interprets an exhibit compared to the next visitor (Kisiel & Anderson, 2010). Feher and Rice’s (1985) research suggests that students are better equipped to learn from an exhibit when they already have some prior knowledge of the content presented and have recently been primed to reflect on all factors impacting the exhibition phenomenon or content. Moreover, their findings suggest that cognitive gain was superior when multiple exhibit experiences presented around the same topic were combined.

Appropriate preparation before exposure to an informal learning activity may even be critical to achieving the desired learning outcomes. DeWitt and Storksdieck’s (2008) review of field trips highlights that prior knowledge is a key factor in learning outcomes from informal learning exhibits. Research in the neurobiology of learning and memory demonstrates that priming, as a result of previous learning experience, changes memory formation (Nelson, 2011). However, as suggested by DeWitt and Storksdieck (2008), content is not the only potentially novel characteristic presented to students in an informal learning experience. Because learners may encounter entirely novel elements in informal learning environments, informal learning is particularly vulnerable to influence by the novelty of the setting (Falk & Balling, 1982; Falk, Martin, & Balling, 1978; Orion & Hofstein, 1991a, 1991b). In fact, novelty may
exert an inhibitory influence on learning for students and other visitors (Balling & Falk, 1980). Lack of access to informal experiences leaves children from low-socioeconomic status (SES) families at greater likelihood for having to cope with novelty prior to being ready to focus on informal learning content, and, therefore, SES is an important demographic consideration in this study (Bullard & Hubbard, 2014).

**Novelty in learning**

Orion and Hofstein (1991b) parsed three types of novelty: geographic, psychological, and cognitive. **Geographic novelty** refers to characteristics of the learning environment, which includes the facility itself, possible auditory or visual distractions, and other physical characteristics that may alter the learning process. **Psychological novelty** addresses the mechanisms through which information is disseminated to learners, such as reading display boards, listening to audiotapes or oral presentations, manipulating artifacts, and participating as an individual or in a group. **Cognitive novelty** involves prior knowledge or priming, familiarity with the content, and comprehension of vocabulary.

Although it has been suggested that student engagement in novel learning environments allows learners to experience a range of positive feelings, attend to the experience, and find meaning in what they are learning (National Research Council, 2007), only an optimal level of novelty is associated with positive learning outcomes. For example, psychological and cognitive novelty can have a positive impact on student engagement in classroom settings (Palmer, 2009); however, if learners in an informal context find a setting to be too novel, then they first embark on an off-task, exploratory phase of behavior, prior to being receptive to prescribed assignments (Kubota & Olstad, 1991). Thus, novelty has important implications for groups that traditionally have less access to informal learning experiences, such as students with lower SES levels or those from cultures traditionally less embedded in science (Migus, 2014). Because science itself has been identified as a culture, scientific practices may be more or less culturally relevant and, therefore, differentially valued amongst students from different communities (Migus, 2014). Lack of familiarity with an experience, environment, or field of study can directly interfere with content learning, task orientation, and level of engagement (Falk et al., 1978).

Researchers who take a constructivist perspective of museum learning (e.g., Clayton, Fraser, & Saunders, 2009; Lankford, 2002) have directed attention to both visitors’ affective readiness for learning in novel situations and prior knowledge through narrative interviews and observations (Falk, 1983; Falk & Balling, 1982; Orion & Hofstein, 1994). However, perhaps because of the difficulty and time-consuming nature of arranging in-school, instructed orientations, few studies of prior knowledge have taken an experimental approach to reducing the novelty of field trip content for learners. For this reason, we adopted an approach that experimentally manipulated prior knowledge of students before visiting a zoo to test the effect of knowledge on field trip engagement.

**Engagement**

Student engagement is a likely mediator of learning outcomes (Finn, 1993; Marks, 2000) and is readily measured in an informal setting (Skinner, Wellborn, & Connell, 1990). When using engagement, or indicators of engagement in research, recognizing that the research focus can be on involvement with the process or object of study is important. **Student engagement with the learning process** requires getting students actively involved with the topic during or after the
experience; student engagement with the object of study refers to student learning that is stimulated or enhanced directly through learning objects, and, therefore, is more readily observable. In the context of informal education, learners may engage with both the process and artifacts of study to varying degrees due to different student backgrounds, as previously discussed. For this study, immediately observable engagement with the learning objects was central to the research.

Some researchers have used open reflective documentation practices following group observation to measure cognitive gain and subject engagement of field trip students (Orion & Hofstein, 1994), and others have directly tallied verbal and body language cues toward the subject matter as indications of cognitive engagement with and attention to exhibits (Kirchgessner & Sewall, 2015; Martin, Falk, & Balling, 1981). For example, learner posture, body orientation, attention point, allocation of attention time, facial expression, and social interactions have been used as observable cues showing immediate engagement with the learning object (Kirchgessner & Sewall, 2015; Martin et al., 1981; Serrell, 1998). Because there is consistent use of similar observable cues among these researchers, in this study we define cues that demonstrate attentive, neutral, and inattentive learner stances with the objects of study. The direct tally of verbal and body language cues provides a consistent, unobtrusive method for comparing attention between the groups (Serrell, 2010).

Addressing gaps in current research

After enhancing participation in the learning process, we measured student engagement with the object of study by addressing the primary question: “Will an increase in prior knowledge affect the engagement of student visitors to a zoo exhibit as measured by attention to the exhibit?” Furthermore, we wanted to explore, “Do differences in other student variables, such as group size and SES, affect student engagement differently under these different prior knowledge treatments?”

Our hypothesis proposed that level of engagement at the neuroscience exhibit will be greater for students who participated in a brain anatomy preparatory lesson intended to increase their prior knowledge, compared to students taught an unrelated preparatory lesson on the heart. A quasi-experimental design was used to test the hypothesis that increasing prior knowledge will elevate behaviors showing engagement with presenters and exhibit materials among 210 7th-grade students in an informal learning environment. Furthermore, the SES of students from the participating schools varied, allowing for exploration of the impact of SES on engagement and possible interactions of SES with preparation.

Method

Setting

The setting for the observation of informal learning was a local, urban zoo, where students spent half of their time exploring the zoo in small groups guided by school chaperones and half of their time rotating through a set of ten temporary, interactive, indoor learning exhibits created by neuroscience experts (Rose, Zardetto-Smith, Mu, & Demetrikopoulos, 2004). The focus of the present data collection was on a specific exhibit whose content centered on brain structure and function compared across several animal species, to illustrate conceptual connections between brain anatomy and animal behaviors. For example, animals that rely heavily on the sense of smell to guide their behavior have a different brain structure than animals that
rely heavily on vision. Visual aids at the experimental exhibit consisted of brain models, preserved human and animal brains, and a poster labeling various structures and functions of the human brain. The content paralleled school curriculum guidelines for the year (Rose et al., 2004).

**Participants**

A total of 210 students approximately 12 to 14 years old from two urban schools located in a major Southeastern U.S. city participated in this study. Pseudonyms are used when referencing the schools. These schools and their 7th-grade science curricula allowed for neuroscience content tie-ins specific to the project design. Eighty-six students were from Connor Middle School, a large district, urban school, and 124 students were from Taylor Middle School, a small district, urban school. Because this research was conducted as a component of an educational partnership between university neuroscientists, middle school science teachers who were candidates for a doctorate in Education, and staff at a local zoo (Pecore, Kirchgessner, & Carruth, 2013), the data are derived from different participating schools from different years, which created an additional within-design variable: Year 1 data were derived from students at Connor (eight groups of 9–12 students; four experimental groups and four control groups) and Year 2 data were derived from students at Taylor (27 groups of 4–8 students; 14 experimental groups and 13 control groups).

The schools participating in this study varied in demographic composition. The Connor student body was over 95% African American, with Hispanic and White students comprising most of the remainder of the student population. Over 82% of students from Connor received free or reduced lunch (72% free, 10% reduced), which qualified Connor as a low-SES school. By comparison, Taylor School was comprised of approximately 50% White, 43% African American, and 2% Asian ethnicities. Taylor had 35% of its students receiving free or reduced lunch (30% free, 5% reduced), qualifying Taylor as a middle-SES school. Connor was located just over 4 miles from the informal learning site, an urban zoo. Taylor was just over 6 miles from the zoo.

According to public school records, both Connor and Taylor were classified as Title 1 schools, meaning they receive federal funding to help support the education of student bodies comprised of students from low-SES homes. According to State data (Georgia Department of Education, 2016), 72.7% of Connor students and 87.4% of Taylor students met or exceeded grade level criteria for mathematics. The data for reading/English Language Arts revealed 90.9% of Connor students and 93.7% of Taylor students met or exceeded grade level criteria. Neither of the schools in this study grouped classes by achievement, needs, or ability level. Therefore, both experimental and control groups from both schools were alike because they contained students with varying academic abilities. Students were assigned to condition by virtue of the classes they were enrolled in, and the classes were randomly assigned to experimental condition.

**Preparatory lessons**

For this study, a content expert team, composed of a university professor and graduate student or postdoctoral teaching assistants, conducted an experimental or control preparatory lesson with middle-school student classes approximately 1 week prior to the zoo field trip. Within each school, classes were randomly assigned to experimental and control groups such that half of the classes participated in a preparatory lesson about the structure and function of the
brain that related to the content of the temporary zoo exhibit on brain anatomy (experimental group), whereas the other half participated in a preparatory lesson about structure and function of the heart (control group). A mixed design was used so that each expert team taught both the heart and brain anatomy preparatory lessons. In other words, approximately half of the students provided with the brain lesson worked with one expert team while the other half worked with the other expert team. Teams returned to classrooms to teach the alternate lesson plan after the field trip, so that all students received both lessons by the end of the school year.

The two preparatory lessons only differed in terms of content and were similar in style and interactive approach. The brain anatomy lesson for the experimental groups was a 50-min inquiry activity in which students heard descriptions of structure-function relationships between brain parts and animal behavior, then worked in groups to design the brain of an imaginary animal, modeled it with clay, and presented their model to their peers and the guest presenters (Demetrikopoulos et al., 2006). The control group received a similar lesson in length and technique to that of the experimental group, but the introduction focused on structure of the mammalian heart and subsequent activities enabled students to work together to map blood flow through the heart and to explore preserved cow hearts. The models and the vocabulary used in the classroom preparatory lesson for the experimental group, but not the control group, were the same as for the brain anatomy exhibit.

**Procedure**

Upon entering the zoo, students participating in that day’s field trip were separated into two groups according to the treatment they received in class before the field trip and then subdivided into smaller groups to view the exhibits. Students in the experimental group were given yellow wristbands, and students in the control group were given orange wristbands. Data collectors were blind to the wristband code and did not know which groups received which preparatory lesson.

Groups spent 12–15 min at the experimental brain anatomy exhibit station addressing structure and function of the brain once during their field trip as part of visiting the neuroscience exposition. The experimental brain anatomy exhibit, which relates back to the preparatory lesson by sharing brain models and vocabulary, is one of 10 neuroscience exhibits and the site of data collection. During the first 5 min at the brain anatomy exhibit, a facilitator used a poster as a visual aid when explaining the structure and function of the human brain. During the second 5-minute interval, students observed and handled models of human and animal brains, put on protective gloves to touch a real human brain, and shared reactions to the texture and look of the human brain. During the final few minutes in this exhibit, students compared human brains with those of other animals using preserved specimens and model brains.

**Analysis**

**Attentiveness, a measure of engagement**

Students’ behaviors were observed only during the brain anatomy exhibit, and not during transition times or at other exhibits. Using general behavior observation in the form of directly tallied verbal and body language cues, researchers monitored attentiveness to the presenter, artifacts, and exhibit engagement indicators. Two pairs of trained observers used observational guidelines from Bogdan and Biklen (2007) to independently record field notes
on student attentiveness while monitoring the students as they participated at each brain anatomy exhibit. A quantitative score was generated by one researcher rating each student at the brain anatomy exhibit for student's level of attentiveness at regular 1-, 4-, and 7-min intervals. Thus, attentiveness was measured three times for each student, and these data were used to develop an average percentage of time spent being attentive, neutral, and inattentive with the brain anatomy exhibit for each group.

The project team developed a list of behaviors to observe for data analysis. Three categories of engagement, developed a priori, were described as (a) attentive: showing positive signs of attention, including active engagement (e.g., reading a poster, repeating terms, touching models, relevant student-student discourse) and passive engagement (e.g., nodding, leaning toward an exhibit, eye contact with the instructor or display materials); (b) neutral: showing neither positive nor negative signs of attention; and (c) inattentive: showing negative signs of attention including off-task motor (e.g., walking away from exhibit), off-task verbal (e.g., discussing unrelated concepts), and off-task passive (e.g., staring away).

Qualitative details of student behavior were recorded consistently throughout their exhibit time by the second researcher. These field notes included group size, key terms used by a student, eye contact, student focus point, interaction with an exhibit component, and use of reference materials to engage with the topic. Researchers reviewed observation notes independently and then collaboratively coded the observation data (Miles & Huberman, 1994) for notable behaviors such as comments, terms, body language, gaze, and physical actions that indicated attentiveness of student group members (Martin, Falk, & Balling, 1981). Observational data from field notes, used in the discussion to support the qualitative results, assisted with triangulating the directly tallied observational data.

Multiple sources of qualitative data (two sets of observation field notes) along with pattern-matching, explanation-building, and addressing rival explanations among researchers, were used to establish validity. This process consisted of two members of the project team coding the observational data independently with discrepancies being resolved by a third team member and building consensus with respect to categorizing students’ observed behaviors. To ensure interrater reliability, two individuals cross-coded the data using simple agreement with an acceptable agreement above 75%.

**Statistical approach**

Because the research questions explore the impact of prior knowledge on student engagement at an exhibit, the role of the preparatory lesson on attentiveness scores generated from field trip data was analyzed first. The percentage of students in each engagement category (i.e., attentive, neutral, inattentive) was analyzed according to the factors of treatment group (heart vs. brain anatomy preparatory lesson) and school (Connor vs. Taylor). Having also identified that Connor and Taylor schools differed in SES, and knowing these differences may indicate differences related to access or values related to science (Migus, 2014), analysis also compared data between the schools. For this, a two-way analysis of variance (ANOVA) was used to test the interaction between school and preparatory treatment on engagement. Prior to proceeding with the ANOVA, Levene’s test for homogeneity of variances was used to make sure the variance within the populations was equal. After conducting the ANOVA, follow-up unpaired t-tests were used following Bonferroni corrections, which creates a more stringent significance requirement when running multiple comparisons. This allowed for an analysis of the impact of multiple variables when comparing students within each of the schools.
Table 1. Mean percent of students rated as attentiveness by school and treatment group.

<table>
<thead>
<tr>
<th>School</th>
<th>Treatment group mean % attentive (SD; range)</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brain</td>
<td>Heart</td>
</tr>
<tr>
<td>Connor</td>
<td>78.50 (19.92; 60–100%)</td>
<td>40.75 (13.00; 24–52%)</td>
</tr>
<tr>
<td>Taylor</td>
<td>79.21 (18.72; 52–100%)</td>
<td>80.85 (14.25; 58–100%)</td>
</tr>
<tr>
<td>Total</td>
<td>79.06</td>
<td>71.41</td>
</tr>
</tbody>
</table>

Note. For School: Connor = Connor Middle School, a low-SES urban school; Taylor = Taylor Middle School, a middle-SES urban school.

Results

Descriptive statistics for the data set are shown in Table 1, which displays mean percentages of attentive students by school and treatment. Connor students in the heart preparatory lesson had significantly lower attentiveness than their schoolmates in the brain preparatory lesson, whereas Taylor students from both preparatory lesson groups had similarly high rates of attentiveness.

The percentage of students attentive at the exhibit varied significantly based on the preparatory lesson plan that was implemented, with brain anatomy averaging 79.06% and heart anatomy averaging 71.41% (see Table 1). The treatment demonstrated a statistically significant impact, as shown in Table 2 ($p = .01$, $\eta^2 = .19$). Further inspection between participating school populations, however, yielded an additional main effect of school and a significant Treatment × School interaction (see Table 2). Connor students differed in attentiveness based on treatment group, but Taylor students did not (see Figure 1). Specifically, for the Connor students, the percent of students observed as attentive exceeded the percent of students observed as inattentive in the brain anatomy groups, whereas the percent of attentive students was lower or similar to the percent of inattentive or neutral students in two of the four heart anatomy groups (Figure 1). Concomitantly, the percent categorized as neutral or inattentive was lower in the Brain preparatory groups than in the Heart preparatory groups. For Taylor students, both brain and heart preparatory groups displayed behaviors more like the Connor Brain preparatory groups, with the vast majority of students categorized as attentive and few students as inattentive.

The contrast between Connor and Taylor was revealed by a significant interaction between school and preparatory treatment on engagement, using a two-way ANOVA. Levene’s test for homogeneity of variances ($F_{3,31} = 0.330$, $p = 0.804$) was not violated, and we continued with factorial analysis. Both school (S) and treatment (T) were statistically significant as individual variables; the interaction between them was also significant and required follow up analysis ($p < .01$, $\eta^2 = .22$; see Table 2).

Table 2. Analysis of variance summary table for attentiveness levels, 2 x 2 factorial design: School × Treatment.

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of squares</th>
<th>df</th>
<th>Mean square</th>
<th>$F$</th>
<th>Sig.</th>
<th>Partial eta squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>School (S)</td>
<td>2568.810</td>
<td>1</td>
<td>2568.810</td>
<td>9.528</td>
<td>.004**</td>
<td>.235</td>
</tr>
<tr>
<td>Treatment (T)</td>
<td>2012.055</td>
<td>1</td>
<td>2012.055</td>
<td>7.463</td>
<td>.010*</td>
<td>.194</td>
</tr>
<tr>
<td>S × T</td>
<td>2392.115</td>
<td>1</td>
<td>2392.115</td>
<td>8.873</td>
<td>.006**</td>
<td>.223</td>
</tr>
<tr>
<td>Error</td>
<td>8357.799</td>
<td>31</td>
<td>269.606</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>212467.00</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. School compares Connor and Taylor. Treatment compares preparatory lessons (Brain and Heart). *$p < .05$. **$p < .01$. 
Figure 1. Student attentiveness level by school and treatment. Percent engagement = number of intervals at which each student was engaged at each level divided by the total number of intervals measured between all students within a treatment group; Engaged = actively showing positive signs of attention; Neutral = showing neither positive nor negative signs of attention; Disengaged = actively showing negative signs of attention such as looking away or discussing unrelated concepts.

Because the research questions asked if prior knowledge improved engagement, and the schools varied in other variables (e.g., SES), possible interactions between school and treatment were tested. Figure 2 represents the percentage of students who were rated as attentive by treatment and school. Follow-up unpaired t tests compared the percent of students engaged from Connor, and revealed significant differences between experimental and control groups ($t = -3.539$, $df = 5.6$, $p < .05$, with a significant $p$ following Bonferroni correction for multiple $[n = 2]$ comparisons). In contrast, unpaired t tests failed to reveal significant differences between experimental and control groups from Taylor. In other words, a statistically significant positive difference in engagement was shown for Connor students who received the brain anatomy preparatory lesson.

Finally, a one-way ANOVA was conducted to examine the effect of group size on the percent of students engaged at a high level, and revealed a significant correlation between group size and engagement, $F(1,35) = 9.337$, $p < .05$, $R^2 = .211$. This trend revealed an inverse relationship between group size and engagement. Approximately 21% of the variance between group engagement can be accounted for by group size. However, the main effect of group size

Figure 2. Interaction of attentiveness by school and treatment.
is not responsible for the within-school differences because group sizes were proportionately distributed within each school.

Discussion

Engagement was determined in this study by measuring student attentiveness through positive behavioral signs like touching models, relevant student-student discourse, referring to the exhibit poster, body language, and eye contact with the exhibit facilitator. The creation of categories based on consistent patterns in the data allowed us to address the research questions about attentiveness during students’ informal learning experience. Researcher observations aligned with the impact categories from the National Science Foundation’s *Framework for Evaluating Impacts of Informal Science Education Projects* (2008), including Engagement and Skills, both of which align well with the National Research Council’s “Strands for Assessing Learning Outcomes in Informal Science Settings” (Fenichel & Schweingruber, 2010). “Engagement” is roughly equivalent to Strand 1, “sparking interest and excitement,” and “Skill” is roughly equivalent to Strand 5, “using the tools and language of science” (National Science Foundation, 2008, p. 110).

Experiencing a formal preparatory lesson on content related to a field trip exhibit generally increased some, but not all, students’ engagement at an informal education exhibit, apparently due to an increase in prior knowledge. Student attentiveness data demonstrated that students engaged more deeply and consistently with the brain anatomy exhibit when they had a preparatory lesson related to the exhibit. Experimental groups from both schools demonstrated on-task behaviors by showing and discussing the animal models, asking and answering questions, and often continuing their discussions about the brain with each other and the instructor after the allotted exhibit time ended. The Connor control groups, however, exhibited more off-task behavior, took part more frequently in off-topic conversations, were at times rambunctious, and sometimes left the exhibit area.

Interestingly, Connor students clearly differed in their level of engagement according to their treatment condition, with experimental groups demonstrating higher percentages of attentiveness than their control group counterparts, whereas Taylor students demonstrated equally high percentages of attentiveness across treatment conditions (failing to support the hypothesis that increased prior knowledge will result in higher engagement with the exhibit experience). Yet, Taylor students in the experimental group demonstrated a different benefit from the preparatory lesson since they accessed and used their prior knowledge during the zoo exhibit lesson more than their school-matched controls.

Explanations for the difference between schools

Novelty factors

Although prior knowledge was the manipulated variable in this study, it is possible that unmeasured variations between the schools may also account for the differences observed in this study. The preparatory lessons were designed to decrease cognitive novelty for some students by enhancing prior knowledge in the experimental groups but not the control groups. Prior exposure to zoo-like settings were likely to be distributed evenly across all student groups within each school, but the differences in zoo experience history may vary between the school populations in this study. This other variable may be responsible for the pronounced difference in attentiveness by treatment at Connor but not experienced with Taylor.
**SES and informal education experiences**

The effect size (partial eta squared) from the ANOVA analysis suggests that approximately 22% of the variance in attentiveness levels can be attributed to the interaction between school and treatment. Although it is not certain, the data leads us to believe that SES played a major role in the outcome. Access to, and familiarity with, informal educational settings like zoos are positively correlated with SES (Hanna & West, 1989), with higher-SES students exhibiting more task-oriented exploratory behaviors, presumably due to increased access to and familiarity with informal learning environments (Kubota & Olstad, 1991). As Orion and Hofstein (1994) discovered, all three forms of novelty (geographic, psychological, and cognitive) impact student behaviors during a field trip. The impact of a preparatory lesson may be most significant for students with limited informal experiences. Given the nature of the interactive zoo station design, it would be prudent to measure prior zoo and museum access in future studies to see if these variables further impact participant attentiveness. Moreover, the quality, and not just quantity, of prior informal learning opportunities may be relevant to this disparity, as Gerber, Cavallo, and Marek (2001) demonstrated. In the future, linked interplay between novelty factors and possibly a novelty threshold should be considered when preparing educational science excursions.

**Implications**

One challenge for science educators is to meaningfully diminish the discrepancies between students’ prior knowledge and the content to be presented, while maintaining a level of novelty that motivates and excites learners. It can be difficult for teachers to find connections between an informal setting and their curriculum, and they may not have the expertise, tools, or confidence to instruct about topics present in informal learning settings. Even when orientation materials are available, it can be challenging for informal educators to effectively reach field trip audiences prior to their experience to help prepare them for optimal learning (Mortensen & Smart, 2007). Therefore, it is important for formal and informal educators to form partnerships to overcome these obstacles since research suggests that selectively minimizing novelty factors enables students to engage more fully in the learning process (Kubota & Olstad, 1991). Indeed, providing visitors to site orientations has demonstrated increased likelihood to learn (Falk & Dierking, 2000; Kubota & Olstad, 1991; Orion & Hofstein, 1994; Serrell, 1998). One example of assisting with orientation lauded by Falk and Dierking (2000) is the on-site video at the Cahokia Mounds State Historic Park, because of its innovative strategy to prime visitors to the learning objectives while seamlessly orienting them to the exploration space and historic context. This strategy allows museums to set a common starting point for scheduled and drop-by visitors, although the elaborate immersion and introduction may not be as plausible with organizations featuring numerous themes and exhibitions.

Similar approaches occur at some zoos. For example, the Denver Zoo has taken the initiative to present online, play-based itineraries for multiple regions within the zoo and providing the public with orientation materials targeting youth. In 2011, Smithsonian’s National Zoo, recognizing teacher access limitations to online resources, uploaded a short teacher orientation video to Teacher Tube that encourages field trips and orients educators to the facilities. With the ever-growing prevalence of accessible, streamlined infographics, onsite and online digital orientation materials are worth exploring in zoo and museum settings.

Deliberate partnerships between formal and informal educators may enable informal educators to identify a somewhat uniform background of the visiting school group and to design exhibits or exhibit-focused lessons that tap into that background as the basis for new
knowledge acquisition. Conversely, collection of preliminary information about the informal learning environment, both content and physical environment, may enable formal educators to prepare their students for the informal experience.

Although students from low-SES communities may not have opportunities to visit zoos and museums with their families due to associated costs, museum access within school districts is leading to increased visitations by schools from areas of social deprivation (Hooper-Greenhill, Phillips, & Woodham, 2009). Therefore, how students are familiarized with zoos and other museums may differ by SES, with low-SES students having access primarily through school excursions and middle- and upper-SES students having more family or individual-based, free-choice exposure to these settings. Our study suggests that students from low-SES schools may especially benefit from preparatory lessons before visiting informal science institutions, which is especially important given the increased visitations by schools from low-SES communities.

This research suggests that there are several considerations for educators to address when working with middle-school-aged groups. First, all students, but especially those from lower-SES backgrounds, may engage more with their field trip experience if they participate in a preparatory lesson related to the field trip content. It should be noted that our research indicates it was the content of the preparatory lesson that was critical for this outcome and not the fact that the students had the opportunity to interact with content experts since both groups had prior exposure to content experts. Thus, the content pre-exposure could be accomplished with existing orientation-type programs that could be expanded or modified to include content-related elements.

To best prepare students for a field trip, several actions should be considered for informal learning venues, while also considering the observation of DeWitt and Storksdieck (2008) that teacher implementation of preparatory lessons varies. Presenting some of the visual and manipulative teaching materials associated with the exhibit, and using a similar instructional approach to the exhibit lesson, may increase engagement. Video introductions to the informal learning environment itself may be beneficial for all students, through its potential reduction of geographic novelty.

Limitations and future research

Future research could strengthen conclusions regarding which factors (prior knowledge and novelty) are most influential on learning. Differences across the present experimental and control groups are most likely explained by differences in prior knowledge, whereas differences across school populations might be explained by differences in geographical novelty, which is implied by prior research on the effect of SES on access to opportunities to visit informal science settings but which was not measured for this project. Future studies should also consider the exploration of culturally responsive measures of engagement to ensure that findings about differential engagement are not due to measurement bias. Additional exploration could investigate the extent to which factors individually affect student engagement, learning, and retention in a wider variety of informal settings and across schools from a wider variety of demographic backgrounds. Furthermore, development of an instrument to measure participants’ familiarity with and previous experiences in the informal setting would help inform outcomes.

Future studies should explore the impact of prior experience with relevant vocabulary on learning at an informal setting. During Year 2 of this study, pilot data was collected on vocabulary use with the Taylor group. The use, depth, and frequency of content-specific vocabulary during interactions among students and facilitator may indicate conceptual familiarity (Falk
& Needham, 2011). Although all Taylor groups were observed to show attention throughout the experience, only students experiencing the related preparatory lesson demonstrated familiarity with or use of brain-related knowledge through vocabulary words.

**Conclusion**

The present results demonstrate that groups receiving a preparatory lesson related to field trip content benefit by increasing their attentiveness level at the field trip site. Initial findings also suggest that another factor, SES, interacts with prior knowledge, perhaps by impeding engagement in new or unfamiliar environments. This finding suggests that zoo and museum educators and community partners should continue to develop curriculum that emphasizes learning content for use prior to a field trip. Further research should address how familiarity with an informal educational environment may influence learning, and how this and other types of novelty may interact with SES-related variables. Institutions looking to increase student engagement, learning, and retention might consider expanding orientation programs to include content materials that encourage teachers to help their students preview the related topic. The present study could enable informal educators and their community partners to reduce unfocused student visitor behaviors because results demonstrate that these are not due to uncontrollable internal factors, such as student personalities or their school system, but rather due to external and controllable factors, such as potentially distracting high degrees of novelty or low levels of related prior knowledge.

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