Fostering Critical Thinking in Science Museums through Digital Augmentations

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Abstract: This study investigates the effects of augmented reality visualizations on conceptual understanding in a science museum setting. We build on previous studies of visitor behaviors to analyze how participants engage in two designed conditions illustrating learning that occurs with and without the digital augmentation. Results show increased cognitive (critical thinking) skills when the augmentation is enabled that may lead to increased conceptual gains. We illustrate how this research contributes to three important areas of identified need in the informal science education literature.

Introduction

The recent National Research Council report on learning science in informal environments (Bell et al., 2009) examines the potential that non-school settings have for engaging learners in real-world scientific investigation. The NRC report and others (e.g., Rennie et al., 2003) highlight three areas of need for systematic studies. First, there is a need for more research and clear evidence that indicate improved conceptual and cognitive gains. Second, as more educational technologies are being used to assist in the development of conceptual knowledge, research is needed to know how digital platforms improve the learning experience in these settings. Finally, while designed interactive activities have been shown to increase scientific skills such as manipulating and observing, higher order inquiry skills such as critical thinking and theorizing are less often demonstrated.

Theoretical Considerations

Although digital devices have been tested in museum settings (Szymanski et al., 2008), little is known about their conceptual impacts. This is partly due to the free-choice, episodic nature of informal learning, which makes capturing and measuring learning gains difficult. Researchers have also attributed challenges in promoting deep learning in informal settings to the nature of visitor experiences. For example, McManus has characterized visitor behaviors in terms of "hunter-gatherer groups who actively forage in the museum to satisfy their curiosity about topics and objects that interest them" (1994, p. 91). McManus suggests that intended objectives can still be met if the interest levels are high enough. Unfortunately, many devices are never attended to sufficiently for learning impacts to take effect. Some literature highlights the potential for augmentations to enrich learning events to encourage genres of critical thinking like reflection in a museum setting (Price & Rogers, 2004). However, little empirical research demonstrates this effect. As the importance of fostering critical thinking skills grows (Luke et al., 2007), we are interested in promoting them through augmentations.

Methodology

The investigation used a digitally augmented device called "Be the Path" that illustrates electrical conductivity and circuits. Participants for the study (N=40) were recruited from 6th and 7th grade classes from three schools located in a high needs urban school district with an average of 92% of students qualifying for free or reduced price lunch. Students were randomly assigned to two condition groups. Condition 1 (C1, n=18) served as the control with no digital augmentation. Condition 2 (C2, n=22) encountered the digital augmentation.

Three data sets were collected and analyzed through a mixed-methods approach: time on task; a pre- and post-intervention conceptual knowledge survey; and observation field notes which were coded using the Critical-Thinking Skills Checklist described in Luke et al. (2007). Students' time on task averaged 2.7222 minutes for C1 and 3.2273 minutes for C2. A t-test analysis revealed no significant difference between the means. Figure 1 shows pre- and post-intervention conceptual knowledge survey mean scores. For C1, the difference in mean scores was .3889 with a standard deviation of 1.8194. A repeated-measures ANOVA indicated no significant increase between pre- and post-intervention (p=.377). For C2, the difference was .7273 with a standard deviation of 1.0771. A repeated-measures ANOVA indicated a significant increase between pre- and post-intervention surveys (p=.005) with an effect size of .323. These results imply that, although C2 students didn't spend significantly more time with the device, the augmentation's impact may have helped to improve understanding. Figure 2 shows a comparison of the total frequencies obtained between the conditions for each component, which were adjusted for equal n. Students in Condition 2 did better in four of the seven skills. However, a 2 x 2 chi-square analysis revealed that only Interpreting showed a significant difference, x^2=3.367, p=.067. Differences in frequencies observed for all other components were not significant.

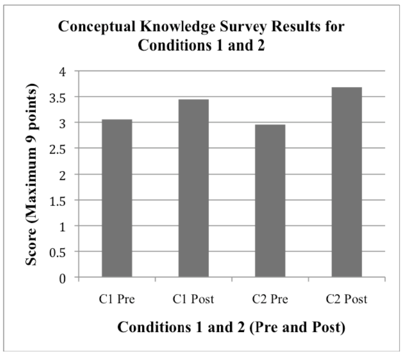

Figure 1. Mean Raw Scores for Pre- and Post-Intervention Conceptual Knowledge Surveys.

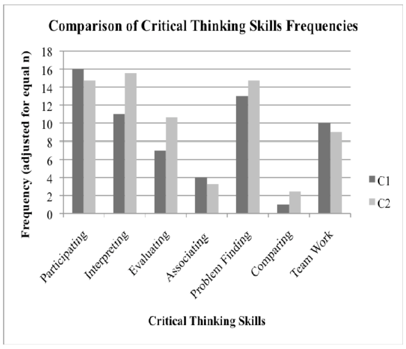

Figure 2. Frequencies of Critical Thinking Skills Observed in Conditions 1 and 2.

Discussion

Our goal was to investigate how digital augmentations improve conceptual understanding and cognitive skills given the specific nature of informal learning. We hypothesized that engagement would be longer and deeper when augmentations were used. When we analyzed the field notes for critical thinking skills, we found that students were better able to interpret the scientific phenomenon which may have influenced conceptual gains. This makes sense in that once the students were able to close the circuit by placing their hands in the appropriate configuration, digital electrons flowing around the circuit appeared, which may have served as an important learning scaffold. Characterizing digital augmentations as learning scaffolds is a fruitful approach in that researchers in the learning sciences have written extensively about how scaffolds embedded in digital platforms can enhance learning (e.g., Scardamalia, 2002; Quintana, 2004). In a study of a handheld augmented reality game, Klopfer and Squire (2008) found that students were able to solve simple problems, but required additional teacher supports to resolve more complex issues. Similarly, John and Lim (2007) reviewed medical training augmentations and found that although students learned from the experience, outcomes were enhanced when combined with other pedagogical scaffolds. In future iterations of this study, we focus on increasing the numbers and kinds of scaffolds and also investigate how those scaffolds are best adapted to informal learning.

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