Museum-based Virtual Reality and Middle Schoolers Interest and Engagement in Science

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Abstract: This study explores the impact of an immersive VR experience and middle school students' interest in and engagement with science. Thirteen students completed a VR experience with two components: a virtual laboratory and a game. Afterwards, students were interviewed and asked to describe their experiences. Students consistently reported the VR experience to be enjoyable and engaging. Moreover, the VR experience seemed to trigger a situational interest in science among the students, with some evidence to suggest that this interest could be sustained and developed in the long term. Implications for research and practice are discussed.
Keywords: Virtual Reality,Interest,Engagement,informal science

Introduction

In the last 15 years, the educational community has become increasingly interested in the affordances of technologies like VR. Although VR is not widely available in traditional classroom settings, it has been used in many science museums and STEM after school clubs (Girvan & Savage, 2019; Chen & Toh, 2005). Notably, previous studies of VR have demonstrated a wealth of potential for improving learning outcomes for students (Huang & Liaw, 2018; Chen & Toh, 2005; Cheng & Tsai, 2020).

VR experiences can be categorized as either immersive and non-immersive. Non-immersive VR experiences employ virtual environments that are accessed via computers or apps. Immersive VR experiences tend to involve 360-degree head-mounted devices (HMD) that participants wear. Moreno & Mayer (2002) showed that students who participated in an immersive VR experience demonstrated higher levels of engagement with science content than those who had participated in non-immersive VR. Liu et al. (2020) showed that higher levels of immersion led to higher levels of student achievement. Furthermore, Wu et al. (2020) noted that immersive VR experiences can lead to positive learning outcomes that are maintained in the long-term.

While the literature surrounding the use of VR in educational settings is promising, many gaps remain. We know from studies like Moreno & Mayer (2002) that students appear to be more engaged while participating in immersive VR experiences. However, we also know that engagement comes in a variety of forms and can be measured in a multitude of ways (Pekrun & Linnenbrink-Garcia, 2012). So what does it mean for students to be *engaged* while wearing an HMD and participating in an immersive VR experience? What are they doing? What are they saying? What emotions does the VR experience elicit? How does an immersive VR experience affect other outcomes like a student's interest in science? As VR becomes more commonplace in both formal and informal learning contexts, the need to understand its impacts on students becomes more pressing. In this study, we seek to address some gaps in the literature by investigate the effects of an informal science-themed, immersive VR experience on student engagement and interest in science.

Conceptual Framework

Engagement. In educational research, much has been said about the benefits of promoting student engagement with science. However, there is widespread variability in how student engagement is defined and measured. Making matters more complicated is the fact that a student's engagement with science is often conflated with their interests in science. Interest, while inexorably tied to engagement in a number of ways, is a separate construct which warrants its own research focus. To this end, we have opted to conceptualize the constructs of engagement and interest according to the definitions put forth by Sinatra et al. (2015) and Järvelä & Renninger (2014), respectively.

Sinatra et al. (2015) identify four categories of engagement: behavioral engagement, emotional engagement, cognitive engagement, and agentic engagement. *Behavioral engagement* is the observable act of students being involved in learning. Behavioral engagement typically refers to the actions students take while involved in academic activities. *Emotional engagement* is defined as students' emotional reactions to academic subject areas such as science or to school more generally. Emotional engagement involves interest, boredom, happiness, anxiety, and other affective states, any of which could affect learners' involvement with learning or their sustained effort in doing the tasks. *Cognitive engagement* is defined as the extent to which students are willing and able to take on the learning task at hand. This includes the amount of effort students are willing to invest in VR learning environments, and how long they persist. Finally, *agentic engagement* is defined by the extent to which students exert control over their instruction. Agentic engagement was not analyzed here.

Interest. To conceptualize the construct, interest, we pull from the work of Järvelä & Renninger (2014). According to this conceptual framework, a student's developing interest in science moves through four phases: a triggered situational interest, a maintained situational interest, an emerging individual interest, and a well-developed individual interest. Triggered situational interests occur when a student's curiosity about a relatively unfamiliar subject is piqued by the acquisition of new information. This interest may subside or, through a series of rewarding experiences, may develop into a more personally-meaningful interest in the subject over time. In this way, a student's interest in science progresses from one phase to the next. Because the VR experience in this study was brief (~10 minutes), we focus on how certain aspects of the VR appeared to promote triggered situational interests in science for students. In some cases, we also observed evidence that students might be developing maintained situational interests in science.

Methodology

Study Context. The VR experience was part of the multi-component *Hidden No More* exhibit, which focuses on the discoveries of scientists from underrepresented groups. The VR experience described here includes two components. The first component was a virtual laboratory experience in which learners recreated an experiment originally conducted by Kamāl al-Dīn al-Fārisī in which he discovered that rainbows were formed via the reflection and refraction of light through water droplets. The second component was a VR game which was designed to allow learners to explore the work of Mercedes López-Morales, an astrophysicist who searches for habitable exoplanets using spectroscopy techniques. Each component takes about five minutes to complete. Notably, the two scientists whose work inspired the VR experience, Kamāl al-Dīn al-Fārisī and Mercedes López-Morales, were purposefully selected in order to highlight the stories of scientists from underrepresented backgrounds who have made significant scholarly contributions to their respective fields.

Setting. Data were collected at two sites. The first site was a summer science camp for middle schoolers in a rural location in the southeastern United States. The second data collection took place at a science center where the exhibit is typically housed.

Participants. This study included 13 participants between 6th and 8th grade (see Table 1). While the majority of the students were white, the overall demographics of the study reflect the breakdown within the communities that were targeted for this exhibit. Every participant in this study engaged with all of the components of *Hidden No More*, including both scientists VR experiences .

Table 1. *Participant Demographics (n=13)*

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%				

Data Collection. Three methods of data collection were employed. First, videos of students were recorded as they engaged with the *Hidden No More* exhibit, including the VR experience. Second, semi-structured interviews with participants were conducted upon completion of their engagement with the *Hidden No More* exhibit. As part of these interviews, participants were asked to describe their experiences with the VR. All interviews were transcribed in order to facilitate analysis. Finally, students completed pre- and post- surveys which were designed to elicit changes in the way they viewed science as a result of their experience with the Hidden No More exhibit.

Data Analysis. All video data were analyzed using a combination of inductive and deductive coding techniques. Our codes were intended to capture the various forms of student engagement via students' behaviors, emotions, and dialogue. Some codes were pulled from previous work on student engagement, for example the work of Pekrun & Linnenbrink-Garcia (2012) and Sinatra et al. (2015). Other codes were generated as we became increasingly familiar with the data. Intercoder agreement was established through regular discussions between the co-authors.

A thematic content analysis was applied to the student interview data. This approach allowed us to identify emergent patterns related to students' evolving interests in science as a result of the VR experience. Additionally, in instances where student engagement was difficult to determine by video data alone, student responses to the interview questions were consulted.

Results

Behavioral Engagement. A student's behavioral engagement can be measured by paying special attention to their body language and verbal participation (Jones, 2009). From the video recordings, we observed that students' body language was vivid and impressive: waving their arms in the air, capturing motion gestures, jumping up to grab things, and turning around to find something in the virtual world. Students also engaged verbally with one another and with museum staff while they participated in the VR experience. Verbal engagement was exhibited though students' self-narration of their virtual exploration, exclamations of surprise and awe, and questions about what other students were seeing. Through their body language and verbal participation, all 13 students demonstrated behavioral engagement with the VR.

Cognitive Engagement. Cognitive engagement can be measured through how much effort students are willing to put into challenging tasks and how long they persist during the learning process. It was notable then that all 13 students completed both VR components without giving up and without any intervention on the part of museum staff. It was clear from our observations that students were cognitively engaged in the VR experience. However, it is not clear if this cognitive engagement came as a result of the novelty of the VR experience or as a result of the science content within the VR. Our analysis of the video recordings revealed that students rarely talked about science concepts while participating in the VRFuture phases of this study will seek to provide clarity on this issue. In particular, we are interested to know how cognitive engagement differs between the two VR components, one of which was a virtual experiment while the other was a virtual game.

Emotional Engagement. A circumplex model of emotional engagement, originally developed by Barrett & Russell (1998) and later adapted by Pekrun & Linnenbrink-Garcia (2012), was used to describe students' affective experiences with the VR. This model takes into account students' valences, which can be positive or negative, as well as their levels of activation, which can be high or low. Assessments of students' valences and levels of activation were made via a combination of researchers' observations and students' responses to interview questions.

All 13 students exhibited positive valences throughout the video recordings, indicating that students had overwhelmingly favorable experiences with the VR. Interview data confirmed this finding, as 12 of 13 students reported the VR to be their favorite part of the *Hidden No More* exhibit. Furthermore, 9 of 13 students demonstrated high levels of activation. High levels of activation combined with positive valences indicate that students generally felt excited about their VR experiences. Four students exhibited low levels of activation which, combined with positive valences, would indicate that students felt content with their VR experiences. These findings are in alignment with other studies which show that students tend to find science-themed VR experiences to be enjoyable (e.g. Winkelmann et al., 2020).

Interest in Science. When analyzing students' interests in science in relation to the VR experience, results were mixed. Many of the students' responses to the interview questions seemed to suggest that the VR experience helped students develop a triggered situational interest in science. Consider, for example, the following excerpts which were typical of the sample:

> *…Probably the best information I got was from the VR standpoint because it really gives you a hands-on experience.*

> *The virtual reality made me feel like I wanted to do [science] because it was fun…*

We also observed evidence that students might be developing more maintained situational interests. For example, one student suggested that they were interested in developing their own VR experiences around science:

> *I want to make VR games [about] science…so other people could play it and it could help them learn more about science.*

Another student commented about being interested in participating in more science-themed VR experiences in the future:

> *When I was in the VR, I could see that two other scientists who haven't been finished yet and that made me wonder what they could have discovered that I use in my daily life.*

While these results are preliminary, they suggest further investigation of how the VR experience is impacting student interest in science, unpacking its triggering of situational interest versus long-term engagement with science content. VR experiences such as the one in this exhibit could potentially provide both informal and formal learning spaces with a tool that allows students to engage with science content and processes that have previously been not accessible generating long-term interest and engagement.

Limitations

The sample of participants in this pilot study was too small to produce findings that are generalizable to large populations. Moreover, participants were sampled from summer science camps, indicating that they were already interested in science to some degree. It is also worth noting that while the HNM exhibit was in part designed to allow students from historically marginalized populations to experience science in a different light, the majority of students in this sample were white.

There are also limitations in the way student engagement was assessed. In this pilot study, engagement was assessed primarily through researchers' observations. This was due to the fact that engagement emerged as an important outcome of the VR experience during the data collection process and after the interview prompts and survey questions were developed. In future studies, more methods of data collection will be used to better capture student engagement.

Conclusions and Implications

These results indicate that students found the science-themed VR experience to be overwhelmingly enjoyable and engaging. Furthermore, we found some evidence to suggest that VR experiences like the one described here have potential to promote students' interest in science. While this was only a pilot study, we believe that this research makes important contributions to the field of science education. Though VR and other emerging technologies are reshaping the nation's educational landscape, we have much to learn about how these technologies enhance student engagement and understanding. This research provides a framework for studying VR and student engagement in educational settings. Additionally, it helps to fill in the large gaps in the literature about VR as a tool for promoting student interest in science. As we continue on to the next phase of our study, these findings will allow us to refine our research design and methods of data collection in order to better understand the affordances of VR in educational settings.

References

Chen, C. J., & Toh, S. C. (2005). A feasible constructivist instructional development model for virtual reality (VR)-based learning environments: its efficacy in the novice car driver instruction of Malaysia. *Educational Technology Research and Development*, 111-123.

Cheng, K. H., & Tsai, C. C. (2020). Students' motivational beliefs and strategies, perceived immersion and attitudes towards science learning with immersive virtual reality: A partial least squares analysis. *British Journal of Educational Technology*, *51*(6), 2140-2159.

Girvan, C., & Savage, T. (2019). Virtual worlds: A new environment for constructionist learning. *Computers in Human Behavior*, *99*, 396-414.

Huang, H. M., & Liaw, S. S. (2018). An analysis of learners' intentions toward virtual reality learning based on constructivist and technology acceptance approaches. *International Review of Research in Open and Distributed Learning*, *19*(1).

Järvelä, S. & Renninger, A. (2014). Designing for learning: Interest, motivation, and engagement. In R.K. Sawyer (Ed.) The Cambridge handbook of the learning sciences (pp. 668-685). New York, NY: Cambridge University Press.

Liu, R., Wang, L., Lei, J., Wang, Q., & Ren, Y. (2020). Effects of an immersive virtual reality-based classroom on students' learning performance in science lessons. *British Journal of Educational Technology*, *51*(6), 2034-2049.

Moreno, R., & Mayer, R. E. (2002). Learning science in virtual reality multimedia environments: Role of methods and media. *Journal of educational psychology*, *94*(3), 598.

Pekrun R., & Linnenbrink-Garcia L. (2012). Academic Emotions and Student Engagement. In: Christenson S., Reschly A., Wylie C. (eds) *Handbook of Research on Student Engagement*. Springer, Boston, MA. DOI: 10.1007/978-1-4614-2018-7_12

Sinatra, G. M., Heddy, B. C. & Lombardi, D. (2015) The challenges of defining and measuring student engagement in science. *Educational Psychologist*, *50*(1), 1-13, DOI: 10.1080/00461520.2014.1002924

Winkelmann, K., Keeney-Kennicutt, W., Fowler, D., Lazo Macik, M., Perez Guarda, P., & Ahlborn, C.J. (2020). Learning gains and attitudes of students performing chemistry experiments in an immersive virtual world. *Interactive Learning Environments*, *28*(5), 620-634, DOI: 10.1080/10494820.2019.1696844