Teaching and Learning Using Virtual Reality: Identifying and Examining Two Design Principles of Effective Instruction

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Abstract: Virtual Reality (VR) is perceived to have potential for improving student learning. This project examined two instructional design principles, based on the unique affordances of VR, that informed the creation of lessons tested in classrooms. All groups of students experienced learning gains. In only one of the lessons did VR students outperform the students in the non-VR conditions. These initial findings support the potential learning benefits of VR and the need for further research.

Introduction and background

Virtual reality (VR) is gaining traction as a commercially viable and exciting genre of games and entertainment. Anecdotally, using VR in classroom settings has the potential to foster student learning in new and innovative ways (Dede, 2009), although this assertion has been largely unexamined empirically. In this research affordances are defined as the properties of a technology that can be leveraged by designers, educators and other end-users to support learning process (Norman, 1999), building from the notion of offered by Gibson (1954) that affordances are characteristics of an environment that indicate possibilities for action. It is important to consider, for example, in what ways can the affordances of Virtual Reality, across the different types and extent of immersiveness, align well with teaching and learning goals in order to improve student outcomes? The study focused on 8th grade science lessons, given the abundance of prior research on science teaching and learning that could inform this project, and the availability of science content in the Expeditions library.

This exploratory project examined two design principles of instruction (which we call Instructional Design Principles; or IDPs) that were identified and further developed based on an analysis of the unique affordances of the virtual reality technology used in this study (namely its immersiveness and ability to show scale) and were then used to create two lessons, each implemented in the classroom with multiple VR-related conditions to investigate these principles. The two Instructional Design Principles tested in the classroom study presented here are: 1) Develop Narrative: immerse students in VR stories to engender learning, interest, and empathy; and 2) Create Scale: pair VR with real life experiences to support students' understanding of scale and proportion. The study examines the impacts of lessons designed based on these principles, using an off-the-shelf solution, *Google Expeditions*, that is widely available. The two lessons used in the study were Spirit: Life of a Robot (abbreviated hereafter as Spirit) and Ocean Acidification (abbreviated hereafter as OA).

Study design and methods

The study used quasi-experimental design, involving three conditions: 1) a VR condition (where students participated in an Expeditions lesson using the full Expeditions kit (phones and Cardboard VR viewers), 2) a phone-only condition (where student viewed the same Expedition content on only smartphones without the accompanying VR viewers i.e. using Expeditions in Magic Window mode, and 3) a panorama condition (where students participated in an Expeditions lesson with no technology, using paper printouts of the same photospheres or panoramas from the corresponding Expeditions virtual field trips). These conditions were selected in order to keep the content of the lessons as constant as possible across the conditions while isolating the affordances of one type of technology over another. Students took a pre-test and the same post-test to measure learning gains. Test items and coding schemes were designed using an Evidence-Centered Design (Mislevy & Haertel, 2006) approach to ensure their appropriateness. Each lesson took two 45-minute class periods or one longer 90-minute block period to complete.

The study participants included eight 8th grade teachers at six public middle schools in the San Francisco Bay Area. These eight teachers chose three of their classes to include in the study. Each of the three classes was assigned to one of the three study conditions so that each teacher taught one session of each of the three study conditions. A total of 24 classes (623 students) were involved in the study. Schools and teachers were recruited to enable matching teachers across lessons, to ensure there were as few differences among teachers of each lesson as possible and to represent a set of classrooms that typically have fewer opportunities to integrate technology into their lessons (thus avoiding a typical research challenge of over-recruiting affluent schools) but included teachers with sufficient teaching expertise and personal comfort with technology so that these variables would not negatively impact implementation of lessons. Teachers were surveyed before and after and interviewed after the study to ascertain their attitudes and understandings about the use of VR in classrooms.

Findings

After teaching the Expeditions-based lessons (using the lesson plans developed for this study), most teachers reported that they envisioned a wider range of possible activities they could teach using VR. These impacts were similar for teachers independent of which lesson they taught. For example, before teaching the lesson, when asked how useful VR might be for various classroom activities, teachers most frequently identified activities where students argue a point of view, design their own problems to solve, link hands-on activities to concepts, and work individually in class. After the lesson, teachers most frequently identified activities where students argue a point of view, design their own problems to solve, make a product, and work in small groups in class.

Students' STEM content learning significantly increased during both lessons, across all conditions, as measured by pre and post tests scores and t-test comparisons (Spirit: $n = 285$, $p < 0.001$; OA: $n = 294$, $p < 0.0001$). In the Spirit lesson, students in the VR condition outperformed students in both the phone and panorama conditions on the post-test, as determined by an ANOVA ($p = 0.02$). In the OA lesson, learning gains were equivalent across all three conditions.

Discussion

While the field of education research is just beginning to understand how best to leverage VR for learning, our study's findings point to the potential of VR to transform classroom activities, impacting both teacher and student outcomes. Study teachers were positively impacted in their views and understanding of VR for the classroom after teaching only one Expeditions lesson. This is a significant finding, given the preponderance of research (e.g., Lawless & Pellegrino, 2007) that indicates that teachers often require significant professional development when implementing new technologies in their lessons. Additional analyses not reported here eliminated the possibility that teacher effects, time-in-VR, and differences among students at the beginning of the study explain the difference we see in students' learning in the *Spirit* lesson by condition. Although the effect of VR on learning in *Spirit* is small, the finding points to the importance of future systematic research studies to determine the ways that VR experiences can be designed and leveraged in instruction to maximize the impact of VR on learning. The documented difference in learning by condition after only one 90 minute lesson lends credence to the idea that VR could potentially have larger effects on student learning outcomes. Most importantly, this study provides an example of theoretically-informed investigation of affordances of VR technology, via the use of IDPs, to support classroom learning while demonstrating the need for future study.

Other important factors to examine in future studies must include the types of classroom activities included in the lesson to support learning, as well as the scope of the STEM content presented in the Expeditions tour. The efficacy of classroom activities accompanying VR and the scope and quality of content presented to students within the VR experience will need to be closely monitored in future studies of learning.

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