CIRCL Primer: Virtual Reality in Education

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Overview

Virtual reality (VR) is an emerging platform for creating meaningful, engaging user experiences. VR typically refers to a computer-generated experience of a fictional or real place that you can interact with through words and gesture. Done well, VR can make people feel that they are physically present in the virtual world — and react as if they are in a real world — because the brain buys into the illusion that the experience is, in fact, real. In gaming, VR headsets, hand-held remote controllers, and wearable gloves and suits offer new levels of immersion and interactivity. Beyond gaming, VR is being used in the workplace to help doctors practice surgery, customer-service employees improve understanding of body language, and colleagues feel connected in virtual meetings. VR can even help people develop empathy around (for example) climate change, understand scientific phenomena they can't see, and experience historical events they otherwise couldn't experience (Bailenson, 2018).

From a learning science perspective, VR ties into long-standing themes around how dynamic representations and visualization can support conceptual learning. It opens new opportunities to consider how affect and cognition are mutually supportive in learning processes. And it raises challenging issues of how groups collaborate in virtual spaces, or how learning moves among virtual and everyday group spaces and contexts. As learning scientists, we see an opportunity here, if we are careful. The next sections of this primer present some key learning science lessons and issues for VR. But first, to orient the reader, we provide a brief overview (below) of VR technologies and the related concepts of virtual, augmented, and mixed reality.

VR Technologies. VR is making inroads into education as it becomes more user friendly and economically accessible. VR technologies differ in the amount of immersiveness that they afford, from relatively non-immersive 2D computer-based environments to fully interactive spaces in which you can walk around and interact with objects using headsets and other devices. Headsets typically use either smartphones or computers to drive screen graphics.

smartphone headsets (e.g., Cardboard, HTC Vive, Google Daydream, Samsung VR Gear) offer mobility, but are limited in their processing power and display resolution, which impacts how visually immersive an experience can be. Alternatively, computer-based headsets (e.g., Playstation VR, Oculus Rift) have the benefit of more processing power and better resolution, but restrict the mobility of the user and require special Input devices for each setup. The forms of interaction possible range from no input (e.g., Cardboard), to basic controllers for selecting things within the VR (e.g., Gear, Vive), to additional features like tracking the motion of the user (e.g., Oculus).

Augmented reality. In many discussions of VR in education, there is also a mention of augmented reality (AR). While VR **replaces** your current view with a simulated one, AR **overlays** virtual objects (e.g., labels) onto your current view. A well-known example is Pokemon Go. In this app, your phone's camera shows you a live view of the world around you, and sometimes a virtual Pokemon creature appears in the screen as part of the game. You can then interact with the creature using your phone. Although AR technologies currently lag behind VR technologies, applications of AR are promising for a variety of learning applications: For example, AR applications could project accurately sized dinosaurs into a classroom to helps students to understand scale, support hearing impaired learners by projecting interpreter's signs in the same field of vision as the object, and add additional context or scaffolded support to hands-on activities.

Mixed reality. Features of virtual and augmented reality technology are combined in mixed reality — usually by projecting virtual objects into a real space that is more immersive than augmented reality. For example, the Concord Consortium and University of Virginia have developed a mixed-reality gas laws activity that allows students to interact with a visual molecular dynamics simulation of a gas through tactile inputs spatially aligned with objects in the simulation. Commercial devices like Microsoft HoloLens allow users to interact with the environment without a physical controller.

Key Lessons

What are the potential benefits of using VR in educational settings and/or for educational purposes?

While potential benefits of using VR in educational settings is still being established, there are some key aspects of various VR experiences that are likely to enhance learning as part of well-designed learning activities. Here we discuss a common set of ideas that characterise the VR experience in order to explore the potential benefits for learning.

Immersion vs. presence. In much of the literature on experiences in VR, for learning or otherwise, the dual concepts of immersion and presence are the primary drivers of VR's impact. Intuitively, these ideas make sense, but they should be specified in order to better understand how they are operating. Immersion is the degree to which VR technology can provide an experience of being in a non-physical world by surrounding the user of the VR system in images, sound, or other stimuli that provide an engrossing total environment. Presence is the extent to which the user perceives themselves to be in a non-physical world (e.g., you can see you own hands interacting with objects in the environment). Thus, different systems with same level of immersion may produce different levels of presence for the same user.

Derived directly from arguments that immersion and presence of VR environments can support learning, VR content that mimics visiting or experiencing other places/phenomena is among the most readily available (i.e., "the magic school bus on steroids"). Google Expeditions offers a library of hundreds of "tours" of places and experiences — such as scuba diving in coral reefs, the craters of Mars, and the human respiratory system of a cell. Each is designed to accompany K-12 lessons. Based on a similar principle, higher ed VR uses include access to virtual science labs and tools that would otherwise be too costly or dangerous to provide in real life.

Taking immersion and presence a step further, some VR content is aimed at deepening social and psychological experiences. Virtual journalism aims at placing individuals in the midst of current news stories to develop better understanding of issues and events, but also to establish empathy among users in ways that more traditional news reporting can not. Research on VR has shown its potential to develop more than empathy among users. Bailenson and colleagues have shown that users can experience and reduce impacts of stereotype threat when appearing as a person other than themselves in a VR world (being immersed in another's shoes).

What are lessons learned for designing curriculum and instruction or for designing future research?

While examples of the potential benefits of immersion and presence to support learning (and beyond) spark our imagination, a key question becomes how to best design lessons that employ VR. Like all other learning technologies, the activities in which the VR devices are embedded are the lead factor determining the extent to which the tech can enhance or impede learning. Based on this idea, a foundational principle for using VR in educational settings is to leverage known learning science mechanisms as part of VR activities. For example, embedding VR in constructivist activities, activities that leverage student collaboration, or activities that require students to apply prior or new knowledge in authentic problem contexts is more likely to to draw on the affordances of VR to support student learning. In this vein, two examples of recent research illustrate attempts to establish how VR might extend the impact of known LS mechanisms.

VR and embodied learning. Recent research on embodied learning posits that one's body and one's physical experience play an important part in student learning (Lindgren & Johnson-Glenberg, 2013). In VR learning environments, students can have embodied experiences in and with physical spaces that go well beyond classroom walls. However, the vast majority of VR content available and feasible to classroom teachers is limited to head-mounted VR. Thus, in many cases, the full range of bodily movement is not available.

Augmented and mixed-reality technologies blur the boundaries of one's physical environment and virtual spaces by enabling more freedom of movement within the classroom (or any physical environment), further extending the possibilities of embodied learning.

VR to support science learning. The benefits of the use of simulation in science instruction is well-documented (D'Angelo et al., 2014). The ability to experience and interact with phenomena is extended with immersive technologies like VR. Researchers recently put this idea to the test by comparing student learning in three study conditions wherein students either used VR, photospheric digital media, or panoramic images as part of two science lesson. In one lesson, students who used VR achieved higher gains as measured by pre and post tests, and in the second lesson there were no learning differences by condition (for more details, see Cheng et al, 2018).

This study, among many calls from education researchers, points to the need to further analyze and study the alignment of the particular VR technology and content with the content and learning goals of the lesson in which VR is being used. One approach to specifying this alignment is described by the study researchers as identifying the overlap or coordination of the structure and sequence of learning activities (in which VR will be used), the pedagogical practices that will be employed in the lesson, and the affordances (and constraints) of the VR technology and content to be used. This approach is common among best practices of use of any learning technology, specifically those that are still being explored, but will result in principles of use specific to VR.

Issues

There isn't yet much research available on the uses of VR within educational settings, especially classrooms or informal learning spaces. Thus, we don't know what key dimensions of VR content need to be considered in design of educational content and activities that goes beyond our general understanding of how to implement technologies within educational spaces (see Key Lessons section). However, there are some issues that are specific to VR that need to be considered going forward:

1. **Little current research on how best to align affordances of specific VR tech and content with known learning mechanisms**. The alignment of learning goals with the affordances of specific content in a particular type of VR with particular students is an important consideration of any instructional design. Because there is little research so far into the various affordances of different content within various types of VR, it will be difficult to know the proper alignment of these factors for a while. Research goals for VR might focus on questions around specific **subject matter integration** (social science and science are often given as examples — but what about math and English language arts?), **grade level optimization** (does it provide too much novelty for younger children? What ages best suited?) and **assessment** (such as quasi experimental studies investigating whether students retain content more ably with vs. without VR).

2. **Amount and format of content is limited right now.** While there is a growing amount of content available for VR, it still does not include the wide variety of learning content available in other more accessible formats. There are also very limited resources and tools available for teachers and students to generate their own content or edit content that is available; for many, this will mean using existing content and/or lessons, which may not suit their particular needs very well.
3. P**hysical limitations of using VR with a wide variety of students.** There are a number of issues surrounding the physical limitations of VR: the physical discomfort of some versions of VR that typically increase with the amount of time spent in VR; age limitations on many versions of VR, including Expeditions, which recommends not using it with kids under 13; and students with vision difficulties that may not be able to see the VR content.
4. **Resources required (both financial and technical) in order to implement VR-related instruction in classrooms and educational spaces.** VR technologies, like any new technology, are generally expensive and require a significant investment by the educational agency or group to implement them with any amount of scale. Even less expensive versions of VR, like Cardboard, require fairly recent version of smartphones to be used in the headsets. Other VR technologies are almost prohibitively expensive to be used in classrooms (e.g., a HTC Vive set-up is $500) where they are a supplemental technology. There are also other technology and infrastructure resources that are needed to successful implement these kinds of technologies: charging stations, up-to-date devices, reliable wi-fi (or local networks), ample storage room, and troubleshooting experience or help.

Collaboration among and between students in VR systems is still in its infancy, and there is much work to do in this space. Some VR technologies, such as smartphones, allow for a pseudo-VR mode where, instead of putting the phone up to your eyes, you can keep it at arm's length and use the phone or tablet as a window into a virtual world. This kind of setup could facilitate more collaboration and shared views among students, although it does this at the expense of much of the immersive quality of VR. But again, depending on your learning goals, this might be an appropriate trade-off.

The sheer novelty of VR can also be an issue in classrooms that can impact instruction in multiple ways. First, students could be distracted by their excitement in using a new technology. **Since such excitement fades over time, instructional designers may want to build in extra time in early uses of new technology to get the novelty out of the way so it does not conflict with learning.** Further, short uses of novel technology could over-emphasize the significance of the technology rather than on the content that will result in improved learning outcomes. In other words, the excitement might lead to a spurt of increased student engagement in the lesson but because the excitement wears off, the learning gains may primarily be due to the novelty rather than the actual benefits of the instruction. Research on longer-term use of VR technologies is needed to disentangle this novelty issue and establish more precise thresholds distinguishing between novelty and substantial student engagement.

Projects

Examples of NSF Cyberlearning projects that overlap with topics discussed in this primer.

Augmented and Virtual Reality:

- Catalyzing Scientific Inquiry and Engineering through Wearable Intersubjective Sensation Devices
- EAGER: Making with Understanding
- EXP: Collaborative Research: Cultivating Apprenticeship Learning for Architecture, Engineering, and Construction Using Mixed Reality
- EXP: Collaborative Research: Extracting Salient Scenarios from Interaction Logs (ESSIL)
- DIP: Collaborative Research: Interactive Science Through Technology Enhanced Play (iSTEP)

Stanford Ocean Acidification Experience. A virtual underwater ecosystem where you can experience firsthand what coral reefs are expected to look like by the end of the century if we do not curb our CO_2 emissions. Watch the ocean absorb invisible CO_2 molecules, a coral reef degrade and marine life disappear as the ocean acidifies.

Resources

Google Expeditions – virtual field trips for classroom use
ThingLink – annotate 360 videos and images
zSpace – all-in-one computer with VR and AR capabilities with a suite of learning apps
Alchemy VR – creator of compelling immersive experiences
Immersive VR Education – tools for teachers to create their own content in virtual classrooms
AltSpaceVR – social platform for VR

Readings

References and key readings documenting the thinking behind the concept, important milestones in the work, foundational examples to build from, and summaries along the way.

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