Exploring the Transformative Integration of Immersive Makerspace for Teaching Abstract Science Concepts

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This study outlines the design and implementation of an Immersive Makerspace (IM) using the Mozilla Hubs, an online Virtual Reality (VR) platform accessible across geographical boundaries through mobile devices, personal computers (PCs), and web-enabled VR headsets. This Design-Based Research (DBR) study explores the effectiveness and challenges of "making" in an IM. Learning from the challenges through different iterations, this study aims to platform to foster elementary students' learning of abstract science concepts.

Introduction

Makerspaces are innovative, collaborative, hands-on spaces that allow learners of all ages to learn through making (Sheridan, 2017), inventing, and exploring their interests through creating objects. Making is an active process which involves creating shareable artifacts by constructing, designing, and inventing with tools and materials (Martinez & Stager, 2019). Chen and Cao (2022) found an increased interest in using makerspaces in K-12 settings. However, limited facilities and high maintenance costs hinder rural school districts' makerspace integration (Loertscher, 2015). Additionally, physical makerspaces can have exorbitant membership fees, serve limited affluent audiences, and narrowly focus on electronics, robots, and high-end fabrication tools (Radu et al., 2021; Ratto, 2011). Consequently, these challenges lead educational researchers and practitioners to explore creative ways to support makerspace integration in this context.

One creative solution makes use of Mozilla Hubs, an online social virtual reality (VR) platform accessible through mobile devices, personal computers, and VR headsets. Mozilla Hubs is an applicable, innovative platform which mitigate some of the previously listed challenges. For example, Asino et al. (2022) demonstrated that using a free version of Mozilla Hubs alleviates cost-related and accessibility issues. They designed immersive educational experiences which promoted water and drought monitoring activities via rural and small libraries backyard explorer programs. Learners in this study entered the immersive learning space as avatars to explore the topics of water, drought, and environmental monitoring, interacted with each other, and participated in activities. With this precedent in mind, we followed the same approach and applied similar concepts in designing the Immersive Makerspace (IM) in this study.

Research Questions

This study's purpose is to investigate the effectiveness of IM using Mozilla Hubs in developing a deeper understanding of abstract science concepts, which are often challenging to visualize (Mørch et al., 2023). The following research questions guide this study:

1. What are the perceptions and experiences of doctoral students regarding the usability, accessibility, and overall effectiveness of IM in learning elementary school-level abstract concepts of science?
2. What challenges do participants face in the "making" process inside the Mozilla Hubs virtual space?

Theoretical Perspective

This study operates on the belief that people, means, and activities interconnect through a shared purpose (Hira & Hynes, 2018). The people/participants in this study's first iteration are doctoral students at an R1 University, some of whom are current or former teachers. Means in the context of the study entails the technology-driven practices people use in the virtual makerspace setting. The activities include the making challenge "All About Carbon" and discussions happening in the IM. The shared purpose catalyzes a profound understanding of abstract science concepts through making in a digital environment. In addition to interconnectedness, Papert's (1993) constructionism theory indicates how learners build their comprehension in the IM. Precisely, participants in the IM will actively construct knowledge when engaged in "meaningful" making activities (Martinez & Stager, 2019, p. 34). They can create shareable objects, like different carbon molecule structures.

Literature Review

Previous studies explored using makerspaces as professional development tools (Paganelli et al., 2016; Shively et al., 2020). However, there is limited research on IMs impacting teacher's knowledge sharing within a professional development (PD) setting. Chen and Cao (2022) designed virtual maker-centered activities for K-12 teachers, while Chen et al. (2022) embedded virtual field trips for rural teachers in a makerspace with telepresence robots. Lock et al. (2020) explored the participants' experiences as a maker community in a synchronous virtual makerspace; other researchers expanded on the scope of this space. Furthermore, Radu et al. (2021) developed a mixed-reality makerspace system accommodating on-site augmented reality (AR), remote desktop, and remote VR participants to engage in the making process in a virtual three-dimensional space. However, our study is unique as we aim to design an IM focused on learning abstract science concepts in a social VR platform for rural teachers with limited access to physical makerspaces.

Methods

This study uses the Design-Based Research (DBR) methodology to collect data. Wang and Hannafin (2005) defined DBR as a systemic but flexible methodology aimed to improve educational practices through collaborative analysis of different iterations, design, development, and implementation. This paper reports on the study's first iteration, which includes intervention design and implementation. The research team's primary collaborators, or "co-participants," are doctoral students from an R1 university, some of whom are current or former teachers (Barab & Squire, 2004, p. 3).

The researchers configured the IM using Mozilla Hubs, dividing it into multiple rooms. The 30-minute making challenge took place in Room One with six participants. Data collection involved pre and post-questionnaires, screen recordings of the participants' making processes, observation notes, and interviews. The participants accessed the IM through mobile devices or personal computers (PCs), with the option of using head-mounted displays (HMDs). Three participants used the VR headset for a fully immersive experience, and the other three participants used a PC. All participants chose their avatars and entered the IM room, which contained a 3D carbon molecule model (Figure 1). Participants used 3D construction materials provided by the research team, which included tennis balls and broom handles, to build their molecules (Figure 2).

Figure 1

Carbon Molecule prototype in Room One

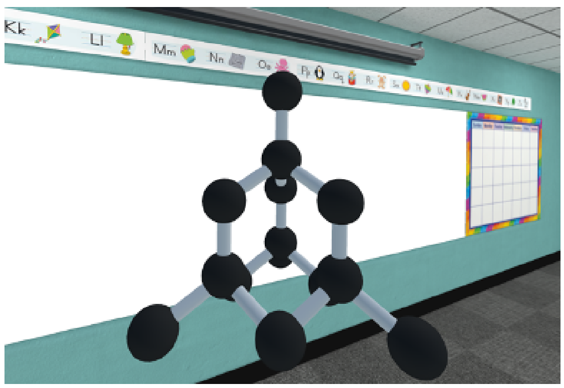
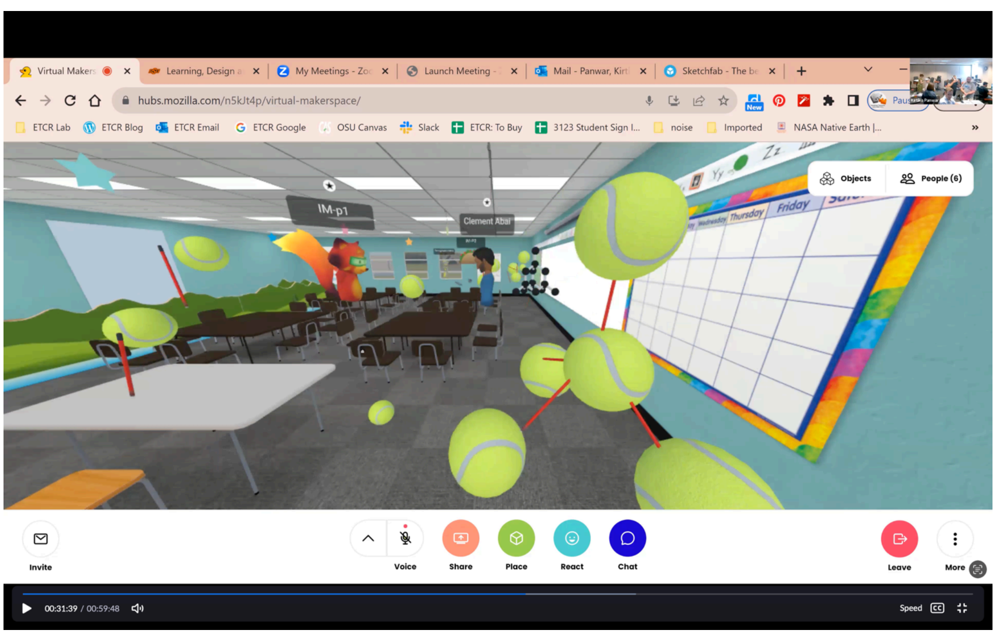


Figure 2

Participants as avatars with 3D materials making carbon molecule



Findings

The research team examined the collected data from all sources. We present the participants' responses in this section. A few participants reported they found Mozilla Hubs to be reasonably user-friendly, offering a simple interface, and reminding them of other games they played. One participant using a PC found its creation capabilities particularly impressive. Another participant using an HMD stated the HMD's rotational capabilities provide a comprehensive field of view, making navigation enjoyable and intuitive. Nevertheless, other players disagreed. First-time VR headset users found it challenging to use the controls and required more guidance. Experienced VR headset users said, "It would resemble more like the tactile experience of makerspace if your controller was the actual hand." Navigation initially presented a confusing challenge for participants using PC and HMD. However, after a few minutes of interacting with the IM, they learned the mechanics of the tennis balls and broom handles, as well as the methods for rotating, cloning, pinning, and unpinning them. Other participants said they struggled to make the carbon molecule because the 3D objects were difficult to manipulate, and the broom handles did not rotate along a specific axis as anticipated to configure the carbon molecule correctly. The participants' responses showed their preferences and curiosity in exploring the IM. One participant wished they had selected VR instead of the PC and said they would try VR in future instances to challenge them. One participant was curious to explore other rooms, the lobby, and the main hall in the Mozilla Hubs. Some participants preferred to have individual makerspace stations so everyone worked in their space without disrupting others' work, while other participants enjoyed navigating the virtual world, as they could observe others' efforts. They also liked seeing the avatars of participants with whom they were not acquainted. Other participants would like more guidance about how to work with 3D elements in Mozilla Hubs, like cloning and linking them together. Two former teachers mentioned that students would thrive in a 3D, interactive educational setting. They also looked forward to the potential for tangible tools to enhance their students' understanding of abstract scientific topics with the inclusion of more 3D elements in the IM.

Discussion

The research team gained insights from the data collected and participants' feedback and will adjust the design based on these findings (Armstrong, 2020). The overall research findings suggest that Mozilla Hubs has good usability and provides an immersive experience for users. Even still, some new players may find the controls challenging. The research team had an additional realization about how participants' preferences about working collaboratively or individually may influence their behaviors in the IM. Based on the participants' feedback, the research team will focus on providing additional makerspace rooms, structured instructions, and more 3D elements to interact with in subsequent iterations. The challenge would be to learn what makes our DBR study effective as we implement future iterations. Expected results from further iterations include a fully developed IM to improve rural teachers' access to makerspace education across geographical boundaries. We also anticipate that PD about IMs could lead to empowered teachers providing engaging science lessons.

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