Promoting the Learning of Complex and Abstract Mathematics Concepts through AR and VR Technology

Western Education

Marja Bertrand, Kelly Cluness & Immaculate Namukasa

INTRODUCTION

Few studies examine Augmented reality (AR) and Virtual reality (VR) in mathematics classrooms and their benefits for teaching and learning (Schutera et al., 2021).

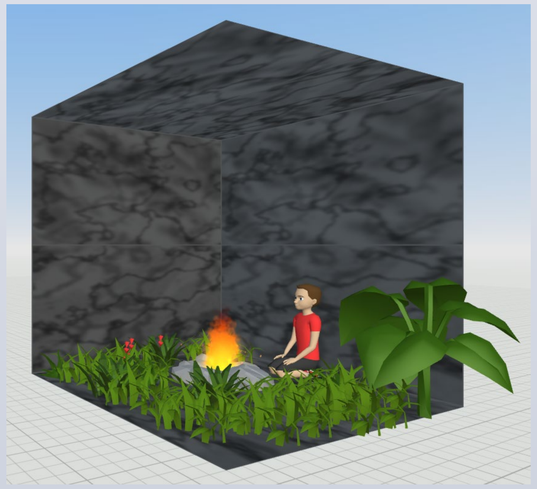
AR and VR are forms of digital technology that can be used to enhance students' long-term memory, increase motivation, decrease anxiety (Schutera et al., 2021, Ardiny & Khanmirza, 2018), and enhance the learning process for students (Chen, 2010).

THEORETICAL FRAMEWORK

We used Borba and Villarreal's (2005) concept of "humans-with-technology" as a theoretical framework to understand how students interact with digital tools like AR and VR. We are interested in how students develop a sense of purpose while actively engaging with digital tools and technology where knowledge is produced through a collective process.

RESEARCH QUESTION

How do AR and VR digital tools increase engagement and enhance the learning of complex and abstract mathematical concepts?



RESULTS

- We found that students were more engaged when they participated in AR and VR exploration centres which allowed them to use physical materials and digital manipulatives (MERGE cube, VR goggles, and AR books).
- Students were inspired to create and animate game-like characters. One student said "I learned how to animate stuff in Cospaces. I could do my own MERGE cube … [and] I felt good through the process." Another student said "I learned how to animate 3D stuff. It made me happy." "I like doing Cospaces. Because it allows you to create virtual worlds and stuff."
- The students used their senses (sight, sound, and touch) to interact with the AR and VR tools. Using the Cospaces Edu app on iPhones or iPads the students were able to interact with their digital animation which was superimposed on the MERGE cube (see Figure 1). The students were able to rotate the MERGE cube, look at their animated characters from different angles and increase or decrease the scale of their 3D objects.
- Students had to consider mathematical concepts such as clockwise and counter clockwise rotations, angles, circumference, radius, distance, and speed when programming their animated characters. Many students used these concepts to model their mathematical thinking during the creation process of their digital animations.
- One student explained, "There's a rooster and a mouse running after each other and fighting." The student demonstrated their understanding of circles, radius, and 360° clockwise rotations by programming the rooster and mouse to run after each other in a circular pattern (see Figure 2). Students also rotated their animated figures 3-dimensionally in the x, y, and z-axis.
- We observed high levels of student interaction throughout the AR and VR centres, where students collaborated with their peers to explore the learning tools together. Those who were more comfortable with the technology supported students who were struggling. One student explained to his peers how to program music or add sound effects to play in the background as the animated characters moved.

Figure 1. Students were able to view, listen and interact with their animation using an iPhone, the Cospaces app, and the MERGE cube.

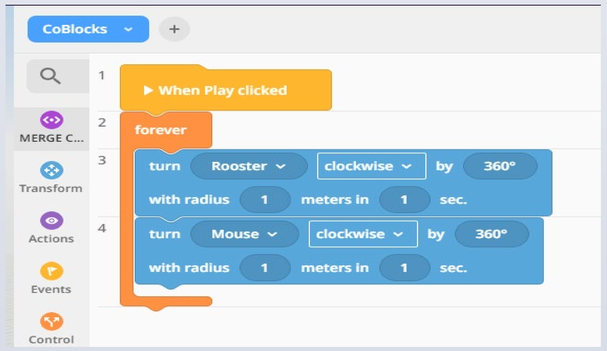


Figure 2. The student animated the rooster to chase after the mouse, by coding the characters to move in a specific sequence, the rooster first then the mouse followed in a circular pattern.

METHODS

Methodology

We conducted a qualitative case study interlinked with Design-Based Research in an outreach STEAM camp. We conducted surveys, interviews, and observations, and took pictures of the students' projects. First, we used pre-existing themes found in the literature (Hubert, 2014), such as AR and VR technology enhancing students' visual and spatial reasoning and used these themes to code the data. Upon further examination, we found emerging themes and codes and used that information to re-analyze the data (Hubert, 2014; Parker et al., 2017).

Digital Tools and Learning Environment

During the STEAM camp, students participated in different activities utilizing various AR and VR technology. They explored several premade AR and VR technologies such as MERGE cubes, AR books, and VR goggles. They also created 3D objects and digital animations using block-based coding in Cospaces Edu and interacted with these animated characters using AR and VR technologies.

Discussion/Conclusion

AR and VR appeared to enhance students' visual and spatial reasoning. We found that "there is a positive correlation between visual-spatial imagination and mathematical achievement" (Schutera et al., 2021, p. 5).

This technology can create a learning space that promotes exploration and experimentation (Chen, 2010). For example, several students used their senses (sight, sound, and touch) while interacting with digital tools.

The incorporation of AR and VR technology provided many opportunities for student interactions, which included but were not limited to the "exchanges of ideas, teamwork, and collaboration" (Buentello-Montoya et al., 2021, p. 6).

In this study, AR and VR showed promising results when teaching simple and complex topics as well as abstract mathematical concepts (e.g., rotation around the x, y, and z-axis, scale factor, maximizing and minimizing volume).

REFERENCES

Ardiny, H., & Khanmirza, E. (2018, October). The role of AR and VR technologies in education developments: opportunities and challenges. In *2018 6th RSI International Conference on Robotics and Mechatronics (IcRoM)* (pp. 482-487). IEEE.

Borba, M. C., & Villarreal, M. E. (2005). Information technology, reorganization of thinking and humans-with-media. In M. C. Borba, & M. E. Villarreal (Eds.), *Humans-with-Media and the Reorganization of Mathematical Thinking: Information and Communication Technologies, Modeling, Visualization and Experimentation* (Vol. 39, pp. 9-27). Springer Science & Business Media.

Buentello-Montoya, D. A., Lomelí-Plascencia, M. G., & Medina-Herrera, L. M. (2021). The role of reality enhancing technologies in teaching and learning of mathematics. *Computers & Electrical Engineering*, *94*, 107287.

Chen, C. J. (2010). Theoretical bases for using virtual reality in education. *Themes in Science and Technology Education*, *2*(1-2), 71-90.

Hubert, T. L. (2014). Learners of mathematics: High school students' perspectives of culturally relevant mathematics pedagogy. *Journal of African American Studies*, *18*(3), 324-336.

Parker, F., Bartell, T. G., & Novak, J. D. (2017). Developing culturally responsive mathematics teachers: Secondary teachers' evolving conceptions of knowing students. *Journal of Mathematics Teacher Education*, *20*(4), 385-407.

Schutera, S., Schnierle, M., Wu, M., Pertzel, T., Seybold, J., Bauer, P., ... & Krause, M. J. (2021). On the potential of augmented reality for mathematics teaching with the application cleARmaths. *Education Sciences*, *11*(8), 368.

ACKNOWLEDGEMENT

This work has been carried out through funding by the following agencies: The Social Sciences and Humanities Research Council, SSHRC, Canada. We would like to thank the following undergraduate and graduate students for their contributions to the facilitation and curriculum development: Jade Roy, Celina Murray, Frank Oliveira, and Derek Tangredi.