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Designing Effective Immersive VR Learning Experiences

Jan L. Plass, Chris Hovey, Aniol Saurina Maso, Fabian Fröhlich, Sounak Ghosh, Al Olsen and Ken Perlin

New York University, New York, USA
jan.plass@nyu.edu

Abstract. How do we design effective immersive VR experiences? *Looking Inside: Cells* is a set of collaborative immersive virtual reality science learning simulations that were designed by applying best practices for learning experience design, taking advantage of the unique affordances of VR for learning. Simulations were designed with input from teachers and students and cover NGSS-aligned middle school science topics in cell biology, including plant cell, animal cell, and prokaryotic cells and their respective organelles, cell specialization, mitosis, and viral mutation. The interaction design of the simulation implements engagements with the learning materials that support deep learning. The collaboration design allows small groups to work on the simulation together. Emotional design was used to induce emotions that are conducive for learning. Classroom integration features are designed to support teachers' use of the simulations through lesson plans, teacher professional development, a teacher dashboard, photo taking, and a spectator mode. Ongoing user research provides feedback from teachers and students that is used to refine the design with the goal to enhance learning outcomes.

Keywords: Immersive VR, Collaborative VR, Science Learning, Emotional Design.

1 Introduction

Looking Inside: Cells is collaborative immersive virtual reality science learning simulations covering middle school cell biology topics aligned to NGSS. The goal of the *Looking Inside* project is to develop research-based principles [1] for the design and evaluation of interactive science simulations in immersive virtual reality that promote collaborative learning. We applied best practices for learning experience design, which include the interaction design, emotional design, and collaboration design of the VR simulations. In addition, we supported the use of the VR simulations by teachers through a number of classroom integration design features. We will describe each of these design features in this paper.

2 Looking Inside: Cells

Looking Inside: Cells is a suite of interactive VR simulations for STEM learning in middle schools. All simulations are designed to facilitate collaborative, active learning experiences for small student groups. Allowing students to jointly explore interactive 3D simulations models provides them with the opportunity to make mistakes and come to a solution through dialogue and negotiation.

Looking Inside: Cells is comprised of several sections. In Build a cell, students use organelles to create an animal, plant, or prokaryotic cell. Specialize a Cell allows students to modify the generic model of a cell to create real, specialized cells that can be found in an organism, such as melanocytes, red blood cells, root hair cells, epidermal plant cells, e.coli, and blue-green algae. In Divide a Cell, students learn about mitosis by moving, removing, and adding organelles to progress the cellular division. Rather than identifying stages of mitosis in images of cells, students will be able to demonstrate their knowledge by creating each stage of the cellular life cycle. Finally, in Viral Mutations, students learn about mRNA, protein synthesis, and virus replication. These simulations were designed following best practices of learning experience design, which will be discussed next.

3 Learning Experience Design

3.1 Interaction Design

Looking Inside: Cells allows learners to actively engage with the simulations, following the INTERACT model [2]. They build cells by moving organelles to create a cell, changing generic cells into specialized cells by removing or changing organelles, and manipulate organelles to create cell division, see Fig. 1. These interaction modes are designed to foster relevant learning [3]. Explanatory feedback is designed to increase comprehension.

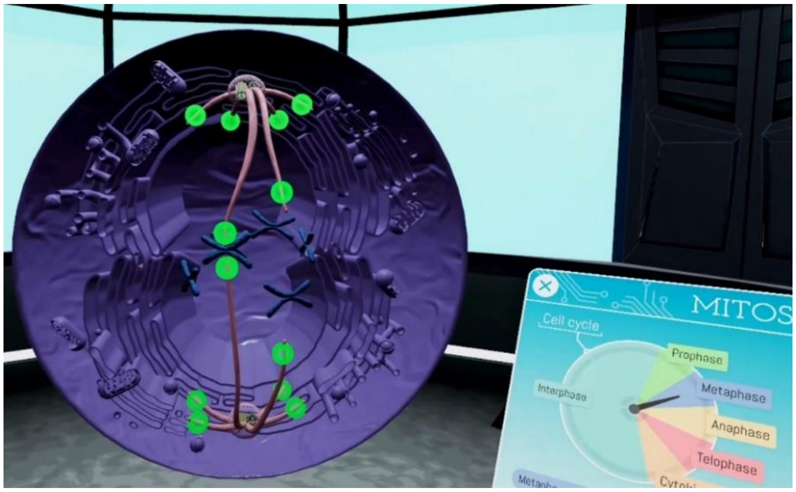

Fig. 1. Interaction Design in Looking Inside: Cells.

3.2 Collaboration Design

A central element of our VR simulation design is their collaborative nature [4]. Small groups of up to 4 learners can collaborate to interact with the simulations (see Fig. 2), and changes made by one user are updated immediately in the display of the other users. This feature allows for remote collaboration of learners and fosters shared cognition.

Fig. 2. Collaboration Design in Looking Inside: Cells.

3.3 Emotional Design

Emotional design is the use of a range of visual, auditory, and haptic design features to induce emotional states in the learner that are conducive to learning [5]. In *Looking Inside: Cells*, we employ two emotional design principles that have been validated by research. Visual design employs warm colors and round shapes where possible [6], see Fig. 3. Sound design employs short loops, a tempo between 70bpm and 110bpm, and a low dynamic range [7] and was designed to reflect and support the effects of the visual design.

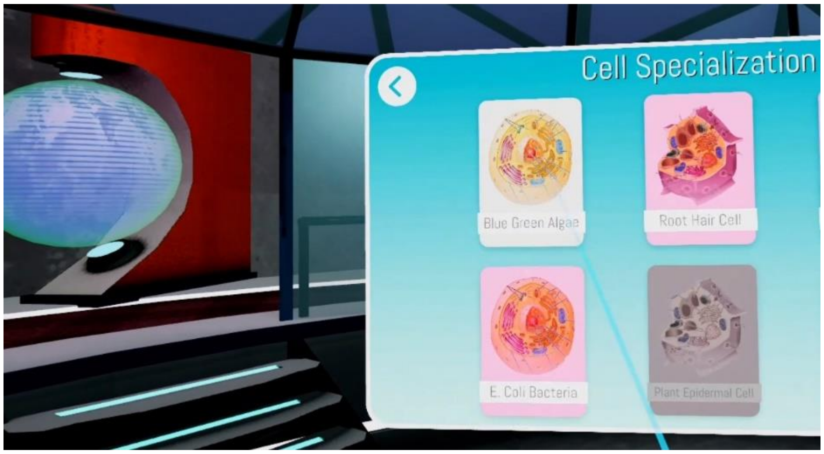

Fig. 3. Emotional Design in Looking Inside: Cells

4 Classroom Integration Design

The integration of the simulation into the classroom is supported by sample lesson plans and protocol suggestions for teachers and teacher professional development in how to use the simulations in their classes. A photo taking feature (see Fig. 4) allows students to take photos of their work in VR and include them in their reports. A spectator mode allows visitors to observe students' activities or to show the VR simulations on a smartboard. A dashboard
[8] allows teachers to monitor student progress and identify students and groups who need additional help.

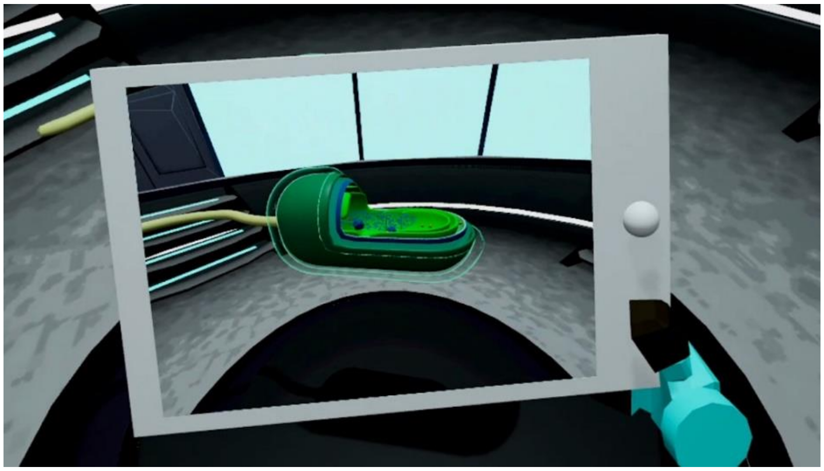

Fig. 4. Taking photos in VR as an example for classroom integration design in Looking Inside: Cells.

5 Conclusion

The design of effective immersive VR learning experiences should take advantage of the unique affordances of VR and base designs on best practices for interaction design, emotional design, and collaboration design. In addition, to support the use of the VR simulations by teachers, classroom integration design features should be included. In *Looking Inside: Cells*, we illustrate these best practices for learning cellular biology in middle school. Features we implemented were designed based on input from teachers and on our prior research. User research is ongoing, and we are refining the simulations according to the feedback we receive. Whether or not the Metaverse will be equitable, inclusive, and affecting positive change will be determined by the quality of the learning materials we design for it.

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