USE OF AUGMENTED REALITY AND IMMERSIVE VIRTUAL REALITY ACTIVITIES IN EDUCATION: EXPLORING APPLICATIONS FOR FACE-TO-FACE, AT-HOME AND HANDS-ON SCIENCE LAB CLASSES

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Abstract

The Chemical and Biological Sciences unit at Montgomery College is exploring the use of new technologies to enhance teaching practices and learning environments as part of the MC 2025 master plan. The MC Foundation calls for educational project proposals through the Innovative Grants program. The proposals must align with one or more specified themes; student success, graduation, completion, retention, transfer, equity and inclusion, newly enrolled students and social justice. Based on work from Bacca, Geroimenko, and Radu, we hypothesize that the use of AR and IVR will increase enrollment, retention, and engagement in the PCR BIOL 150 lab at MC.

Keywords: Innovation, Technology, Amplified Reality, Chemical competences.

USO DE ACTIVIDADES DE REALIDAD AUMENTADA Y REALIDAD VIRTUAL INMERSIVA EN LA EDUCACIÓN: EXPLORACIÓN DE APLICACIONES PARA CLASES PRESENCIALES, EN CASA Y PRÁCTICAS EN LABORATORIOS DE CIENCIAS

Resumen

Como parte del plan estratégico de desarrollo de Montgomery College, la unidad docente de ciencias químicas y biológicas del MC está explorando el uso de nuevas tecnologías para mejorar las prácticas educativas y los entornos de aprendizaje. La Fundación de MC abrió una solicitud de propuestas para proyectos educativos. Los proyectos presentados deben adherirse a varios temas específicos de la convocatoria como éxito estudiantil, retención, finalización, transferencia, equidad e inclusión, y apoyo a estudiantes de primer año. Basados en la literatura actual sobre el tema, esperamos que el uso de AR e IVR aumente la matrícula, retención y participación en el laboratorio ofrecido BIOL 150 de MC.

Palabras clave: innovación, tecnología, realidad ampliada, competencias químicas.

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PROPOSAL NARRATIVE

In alignment with MC 2025 master plan (College, 2019), goal II (*Enhance transformational teaching practices and learning environments*), the Chemical and Biological Sciences unit (CBS) has been tasked with exploring the use of new technologies to teach our students. The goal that the CBS unit pursuits designing, creating, and applying these new educational modalities is to provide our students with another tool to have access to equity and inclusion, student success, and social justice (Bacca *et al.*, 2014; Geroimenko, 2023; Radu, 2014). At the same time, the AHHO lab experiences will help to increase student enrollment, retention, and engagement (Stuckey & Stuckey, 2007), and close the achievement gap for underrepresented students (Delgado *et al.*, 2021).

To support this compromise from the CBS unit, we propose designing, implementing and evaluating two activities, one using Augmented Reality (AR) and one using Immersive Virtual Reality (IVR) that will supplement one of our face-to-face laboratories from the current lab curriculum of one of our science courses. To maximize the number of students reached by this initiative, we have chosen Principles of Biology (BIOL 150), as it is a. required gateway course for science majors and is also taken by students from other programs such as Pre-Nursing, and Physical Therapy Assistant. Combined, these programs account for more than 1,200 students a year. We will prepare the AR/IVR activities to support one of the lab exercises from BIOL 150 (The PCR lab exercise).

Additionally, during the Fall 2021 semester, we designed and developed methodology to teach online and asynchronously two full laboratories from the current BIOL 150 lab syllabus. MC supported this work by granting sabbatical leave to the faculty involved. These laboratory exercises provide our distance learning (DL) students with real AH/HO experiences. We have successfully used the created labs in BIOL 150 hybrid online sections. There is no doubt that the use of AR and IVR assignments and instructional materials will further help to provide our distance learning students with lab experiences comparable with those taken by F2F students.

PROJECT DESCRIPTION

Incorporating Augmented Reality and Immersive Virtual Reality Activities in Biology and Chemistry College Education for PCR Testing in Lab Classes.

Introduction

Biology and Chemistry education involves a lot of hands-on activities that aim to give students practical experience of scientific concepts (Parong & Mayer, 2018). However, the traditional laboratory settings have some limitations that make learning complex concepts and/or lab techniques and skills a challenge (Garay Ruiz *et al.*, 2017; Mayer *et al.*, 2022). For example, during our PCR lab exercise, both

our F2F and DL students do not have a direct meaningful interaction with the thermocycler. As a consequence they do not have the chance to learn how to program it. Augmented reality (AR) and Immersive virtual reality (IVR) technologies have the potential to revolutionize the learning experience in biology education. In this proposal, We will discuss the incorporation of AR and IVR activities in college education for PCR testing in lab classes. Specifically, we will design activities using AR/IVR with the learning goal of allowing students to interact with a thermocycler and teaching students to program the thermocycler to perform a PCR test.

Background

Polymerase chain reaction (PCR) is an essential technique in biology that is used to amplify DNA for various biotech applications, including cloning, sequencing, gene expression studies and disease diagnosis among many others. It is a complex technique that requires a high level of precision, and even minor errors can compromise the entire experiment. Traditional PCR lab classes have some limitations (Bellido García *et al.*, 2022; Garay Ruiz *et al.*, 2017; Pande *et al.*, 2021), such as limited access to equipment (e.g. thermocycler) and reagents, which limit the number of students who can participate as well as the opportunity to learn valuable lab skills required to obtain a job at any laboratory. Furthermore, the traditional approach does not allow students to visualize the different steps involved in PCR, the creation of a program in the thermocycler and how they affect the overall result of the reaction.

Proposal

The use of AR and IVR technologies can overcome the limitations of traditional PCR lab classes and provide an immersive and interactive learning experience. The following activities will be incorporated in the PCR lab exercise for BIOL 150 (Principles of Biology 1, required for Science Majors):

1. AR-based PCR simulation: Students will use AR technology to visualize the different steps involved in PCR. The simulation will allow students to see how the DNA is amplified and how different factors, such as amount of template, proper design of primers, availability of dNTPs, correct buffer, temperature and time, affect the reaction. Our intention is that the simulation will include interactive features that will allow students to control the different parameters and observe the impact on the PCR outcome.
2. IVR-based PCR lab: Students will use IVR technology to perform a virtual PCR experiment. The IVR lab will provide a simulated environment that closely resembles a real lab. The students will be able to program and manipulate the equipment (thermocycler) and pipette the reagents to set up the PCR reaction tubes. The students will be able to observe the different

steps involved in PCR. The IVR lab will also provide a safe and controlled environment where students can make mistakes and learn from them without any negative consequences.

3. Hands-on PCR lab: After the AR and IVR activities, students will participate in the hands-on PCR lab that we offer either in a face-to-face or in an AHHO setting. The lab will provide students with the opportunity to apply the knowledge they have gained from the AR and IVR activities.

Methodology to develop the AR and IVR based PCR simulation and lab

We will focus on the pedagogical aspects of the activity, especially in the design of the activity, making sure there is a clear relation between the AR/IVR and the learning goals, ensuring proper implementation of the activity for the F2F and the DL students, and preparing assessment tools for the activity.

We will obtain the service of a commercial company with experience in Augmented Reality and Immersive Virtual Reality to develop the 3D environment, the objects needed for the activity and the interaction of the user with objects. Careful review of the literature has led us to seeking partnership with a company that will collaborate with us to address the steps mentioned below:

1. *Define the requirements for the AR and the learning objectives for the IVR*: We will define the specific requirements of the AR simulation, such as the different steps involved in PCR, the different factors that affect the process, and the different primers that can be used. We will define the specific learning objectives for the IVR-based PCR lab, such as understanding the steps involved in PCR, the process to program a thermocycler, and ways to handle an automatic pipette.
2. *Choose the appropriate AR and IVR development tools*: We will choose the appropriate tool from the many AR development platforms available, such as ARKit for iOS and ARCore for Android.
3. *Develop the AR models and the immersive virtual environment*: We will develop 3D models of the equipment and reagents used to do a PCR, such as the thermocycler, pipettes, and DNA samples. These models will be high-quality and realistic to provide a good and complete immersive experience.
4. *Create tutorials and instructional guides*: We will develop a tutorial or instructional guide to show students how to perform PCR experiments in the virtual environment. This guide will include instructions for preparing the DNA samples, setting up the PCR reaction, and programming the thermocycler.
5. *Develop the AR and IVR user interfaces*: We will design an intuitive and easy-to-navigate user interface (UI) for the AR and the IVR simulations. The UI will demonstrate how to manipulate the different virtual objects and how to change the parameters relevant for the PCR test and the use of the thermocycler.

6. *Integrate the simulation with the AR and IVR development tools*: This integration will be done carefully to ensure that the simulation runs smoothly and provides a realistic experience.
7. *Test and refine the PCR simulation*: After developing the simulation, we will perform Phase 1 User Testing as a pilot study to ensure that it meets the learning objectives.

THEME CONNECTION

The proposal "Incorporating Augmented Reality and Virtual Reality Activities in Biology College Education for PCR Testing in Lab Classes" connects and supports the following MC Foundation Innovation grant themes:

1. *Student success:* The VR-based PCR lab will support student success by providing an immersive and interactive learning experience that allows students to develop a better understanding of the PCR technique. This will lead to improved academic performance and success in their coursework.
2. *Student graduation, completion, and retention goals:* The VR-based PCR lab can help with student graduation, completion, and retention goals by providing a safe and controlled environment for students to practice and learn without any negative consequences. This will help students stay engaged and motivated, leading to higher completion rates and retention.
3. *Student transfer goals:* The VR-based PCR lab can support student transfer goals by providing a high-quality learning experience that can help students build the skills and knowledge required to transfer to other institutions.
4. *Equity and inclusion:* The VR-based PCR lab will promote equity and inclusion by providing a more accessible and inclusive learning experience for all students. It can help reduce barriers to learning for students with disabilities or limited access to traditional lab equipment.
5. *Part-time students:* The VR-based PCR lab will support part-time students by providing a more flexible and accessible learning experience that can be completed on their own schedule.
6. *Support for newly enrolled (first-time) students:* The VR-based PCR lab will provide support for newly enrolled students by providing a safe and controlled environment for students where they can practice and learn without any negative consequences. We hypothesize that this will help new students feel more comfortable and confident in their abilities.
7. *Social justice:* The VR-based PCR lab can promote social justice by providing an equitable and accessible learning experience for all students, regardless of their background or circumstances. We hypothesize that this will help reduce disparities in access to high-quality learning experiences and support the advancement of all students towards their academic and career goals.

INNOVATIVE SOLUTION

The proposal "Incorporating Augmented Reality and Virtual Reality Activities in Biology College Education for PCR Testing in Lab Classes," as required by the MC Foundation Innovation grant, is an innovative solution for several reasons (Barroso Osuna *et al.*, 2017; Guido Makransky, 2021):

1. *Enhanced learning experience:* The VR-based PCR lab provides an immersive and interactive learning experience that allows students to practice and learn without the need for expensive and potentially hazardous lab equipment. This can enhance the learning experience and make it more engaging and effective.
2. *Accessible and inclusive learning:* The VR-based PCR lab can be accessed from anywhere, making it more accessible and inclusive for all students, including those with disabilities or limited access to traditional lab equipment.
3. *Safe and controlled environment:* The VR-based PCR lab provides a safe and controlled environment for students to practice and learn without any negative consequences. This can help reduce the risk of accidents or mistakes and promote student confidence and motivation.
4. *Cost-effective:* The VR-based PCR lab eliminates the need for expensive lab equipment and reagents, making it a cost-effective solution for colleges and universities.
5. *Innovative use of technology:* The VR-based PCR lab represents an innovative use of technology to improve the learning experience and promote student success. It provides a unique and engaging way to learn complex scientific concepts that may be difficult to understand through traditional teaching methods.

MEASURABLE OUTCOMES

We anticipate the following three measurable outcomes for the proposal "Incorporating Augmented Reality and Virtual Reality Activities in Biology College Education for PCR Testing in Lab Classes" (Barroso Osuna *et al.*, 2017; Guido Makransky, 2021):

1. *Improved student engagement:* One measurable outcome of the proposal will be an increase in student engagement during lab classes. This will be measured through surveys or assessments that evaluate students' interest in the lab activities and their level of participation and interaction with the virtual PCR simulation.
2. *Increased understanding of PCR technique:* Another measurable outcome will be an improvement in students' understanding of the PCR technique. This will be measured through pre- and post-assessments that evaluate students' knowledge and comprehension of the PCR technique, as well as their ability to apply the technique to solve scientific problems.

3. *Higher student achievement:* A third measurable outcome will be an increase in student achievement in biology coursework. This will be measured through assessments of student performance in lab classes and in related coursework, such as exams and assignments. An increase in student achievement may indicate that the VR-based PCR lab is helping students to better understand and apply biology concepts, leading to improved academic success.

STUDENT IMPACT

The proposal "Incorporating Augmented Reality and Virtual Reality Activities in Biology College Education for PCR Testing in Lab Classes" could have a significant positive impact on students in several ways (Barroso Osuna *et al.*, 2017; Guido Makransky, 2021):

1. *Enhanced learning experience*: The use of AR and VR technologies can enhance the learning experience for students by providing a more interactive and engaging way to learn complex scientific concepts. This will help students to better understand the material and improve their retention of important concepts.
2. *Increased accessibility*: The virtual PCR lab can be accessed from anywhere, making it more accessible for all students, including those who may have limited access to traditional lab equipment or who have disabilities that make it difficult to participate in traditional lab activities.
3. *Improved safety*: The virtual PCR lab provides a safe and controlled environment for students to practice and learn without the risk of accidents or injury. This can help reduce anxiety and promote student confidence, which can improve overall learning outcomes.
4. *Increased student success*: The enhanced learning experience, increased accessibility, and improved safety provided by the virtual PCR lab can help to improve student success in biology coursework. This can lead to increased student retention, completion, and graduation rates, as well as improved transfer outcomes for students who plan to continue their education at other institutions.
5. *Equity and inclusion*: The use of virtual and augmented reality technologies can help to promote equity and inclusion by providing a more accessible and inclusive learning environment. This can help to reduce disparities in access to education and improve outcomes for historically underrepresented groups.

By the end of the one-year time frame, the AR/VR-based PCR lab simulation should be fully implemented and evaluated for its effectiveness in improving student learning outcomes in biology coursework. The evaluation of the simulation should inform future plans for expanding the use of AR/VR-based lab simulations in other biology courses. Our plan, once we finish and publish the results of this project, is to apply to obtain federal funding to design, implement, and evaluate AR/IVR

assignments for all the lab exercises done in the BIOL 150 course. Additionally, the AR/IVR simulation development as well as the evaluation of the current proposal will serve as the foundation in the expansion of these technologies in general chemistry lab experiments at the college.

CONCLUSIONS

The incorporation of AR and VR technologies in biology education has the potential to revolutionize the learning experience and improve student engagement and comprehension (Geroimenko, 2023). By incorporating AR and VR activities in PCR lab classes, students will have a better understanding of the different steps involved in PCR and how they impact the outcome. The AR and VR activities will also provide a safe and controlled environment for students to learn and make mistakes without any negative consequences (Guido Makransky, 2021).

The AR-based and VR-based PCR lab should provide an immersive and interactive learning experience that allows students to visualize and perform the different steps involved in a virtual PCR experiment. It should allow students to manipulate the different parameters and observe the impact on the PCR outcome, providing a better understanding of the technique. The VR-based PCR lab will also provide a safe and controlled environment for students to make mistakes and learn from them without any negative consequences (Geroimenko, 2023; Matovu *et al.*, 2023).

Our proposal "Incorporating Augmented Reality and Virtual Reality Activities in Biology College Education for PCR Testing in Lab Classes" offers an innovative solution that leverages the benefits of virtual and augmented reality technologies to enhance the learning experience and promote student success in biology education.

We believe that successful completion of our work has the potential to significantly impact student learning, success, and equity in biology education and that once complete, can be disseminated widely for maximum impact for students in the entire CBS unit at MC which includes biology, chemistry and biotechnology.

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