Board 199: An Overview of VADERs (Virtual/Augmented-Reality-based Discipline Exploration Rotations)

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Abstract

Architectural Engineering and Construction (AE/C) education encounters challenges in cultivating students' proficiency and sustaining a diverse and inclusive workforce due to a lack of students' interest and self-efficacy in the early years of their degree. This paper introduces the Virtual/Augmented-Reality-Based-Discipline Exploration Rotations (VADERs) project, aiming to address these issues by incorporating extended reality technology in an educational approach. VADERs is a set of three virtual AE/C educational modules created based on the Model of Domain Learning framework. Over the first two years of the project, VADER-1 and VADER-2 were developed to enhance first- and second-year students' self-efficacy and retention in AE/C programs. VADER-R, aimed at recruiting high school and community college students into AE/C programs, is under development. VADER-1 and VADER-2 were implemented in 10 courses (405 students) across three institutions in Fall 2023. The impact of VADERs was assessed through reflection surveys guided by Social Cognitive Career Theory, pre- and post-domain knowledge quizzes, and time-stamped click-stream data reflecting student interactions within the virtual environment.

1. Introduction

Architectural Engineering and Construction (AE/C) education faces persistent challenges in enhancing students' proficiency while fostering and retaining a diverse and inclusive workforce [1]. These challenges mainly stem from these programs' heavy emphasis on extensive technical knowledge requirements, such as mathematics, physics, and domain-specific knowledge, in the early years of the degree without effectively fostering students' vision of themselves as engineers or construction managers [2]. Consequently, students, especially in engineering, often lose interest in the early stages of their degree, leading to weakened self-efficacy and considerations of changes to degrees or careers outside the AE/C field [3].

This paper introduces the Virtual/Augmented-Reality-Based-Discipline Exploration Rotations (VADERs) project, a 5-year research initiative supported by the National Science Foundation (NSF) [4]. The primary goal of this project is to address ongoing challenges in AE/C education by harnessing extended reality (XR) technology. The specific research objectives of the VADERs project include the development of VADER modules and investigating the effects of VADERs on students' engagement, diversity awareness, self-efficacy, and retention. Moreover, the project aims to promote the application of VADERs not only within AE/C but also across other engineering disciplines, exploring their potential transferability.

2. Virtual/Augmented-Reality-Based Discipline Exploration Rotations

VADERs consist of a series of virtual educational modules covering structures, lighting, acoustics, heating, ventilation, and air conditioning (HVAC), and construction management disciplines, designed based on the Model of Domain Learning framework [5]. Integrating XR technologies, including virtual and augmented reality, with traditional tasks in AE/C education, VADERs aim to offer students interactive and problem-based learning experiences. The three levels within VADERs are VADER-R, VADER-1, and VADER-2, as presented in Figure 1. VADER-R, currently under development, is designed to engage and recruit high school and community college students into the AE/C program by stimulating their interest. VADER-1 and VADER-2 were developed through collaboration among experts in AE/C subdisciplines, STEM education, and digital technology over the first two years of the VADERs project.

Figure 1. Three education levels of VADERs.

VADER-1 and VADER-2 were created to enhance students' engagement in their first and second years of the degree, ultimately contributing to improved self-efficacy, diversity awareness, and retention in the AE/C programs [6]. VADER-1 and VADER-2 were developed as web browser-based virtual environments using Unity, a game engine software, and Web Graphic Library. Therefore, students can easily access VADER-1 and VADER-2 using a Windows or macOS computer without the need for expensive XR devices and software. This web-based approach also enhances accessibility for students with disabilities who might find it challenging to use other XR technologies, such as immersive virtual and augmented reality [7].

In VADER-1 and VADER-2, students actively participate in an AE/C project focused on designing and constructing different systems in a brain injury clinic. Upon accessing these virtual environments, students are asked to login and are given the opportunity to choose their major, either architectural engineering or construction. The authentication then allows customization of certain features inside the virtual environment, such as a diploma and a hardhat with their names, thus establishing their identity as AE/C professionals. In addition, students select with one of the six project managers, which are avatars representing various races and genders. The selected project manager guides students in carrying out their mission during the project in the virtual environments. These specific features and elements are intentionally integrated into VADER-1 and VADER-2 to foster a sense of belonging and inclusive excellence, particularly aiming to benefit underrepresented students in AE/C education.

VADER-1 was designed to acclimate and develop early competency for first-year students in AE/C by providing an exploration of the subdisciplines (structures, lighting, acoustics, HVAC, and construction management) and fostering an understanding of the interconnectedness of these subdisciplines. The virtual environment of VADER-1 simulates a brain surgery clinic with six rooms, including a conference room, four patient rooms, and an MRI inspection room. Additionally, a virtual environment to further explore the three exterior wall type options is also available. Some images from VADER-1 are presented in Figure 2. In the conference room, students receive instructions for the mission of VADER-1 from their chosen project manager. Afterward, in each room of VADER-1, students engage in interactive experiences that enable them to delve into the implications of design decisions associated with each subdiscipline.

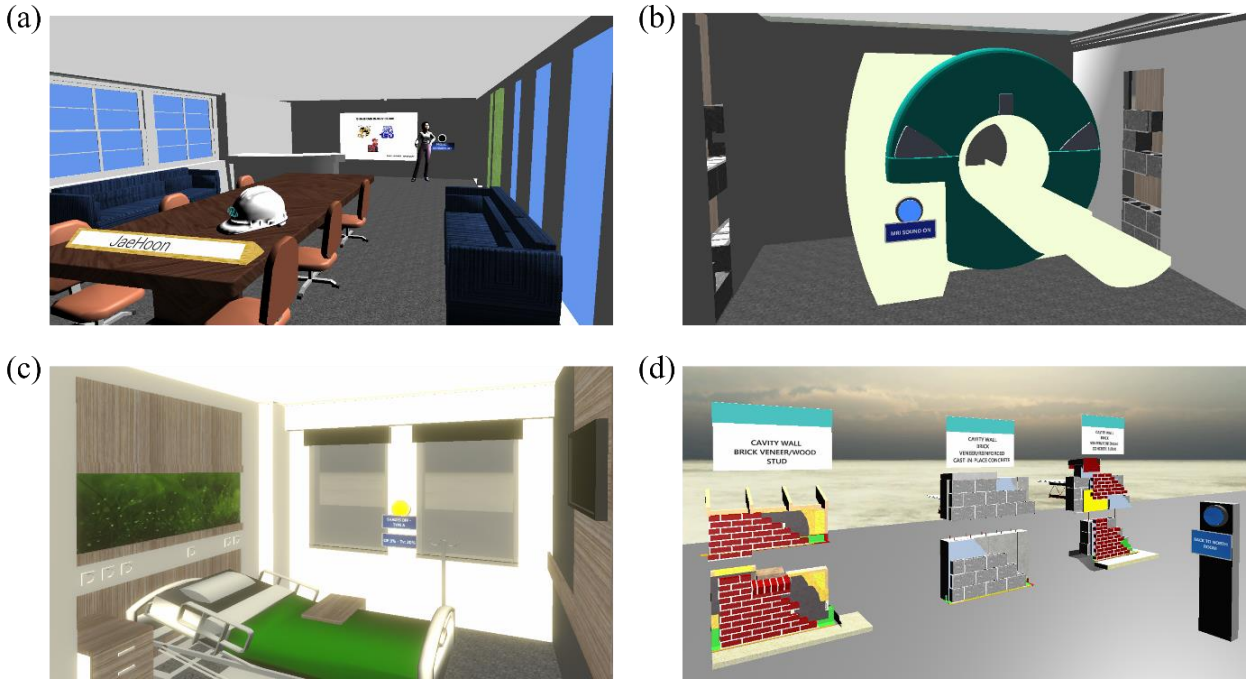

Figure 2. Images of VADER-1: (a) conference room, (b) MRI inspection room, (c) patient room, (d) exterior wall type exploration.

For instance, in a room focusing on scenarios related to the lighting discipline, students can choose from various shading alternatives and visually assess the impact of these choices on the lighting conditions of the room and the visual comfort of the occupants. The mission of VADER-1 revolves around determining optimal decisions across the five disciplines, considering their interrelations and the corresponding implications on the well-being of clinic occupants. This hands-on experience in the virtual setting aims to enhance students' practical understanding of the complexities and interconnected nature of AE/C subdisciplines.

VADER-2 was developed to enhance the competency of second-year students in the AE/C program by providing an interactive and immersive experience in virtual environments. Like VADER-1, the mission of VADER-2 is to make optimal design decisions within the scenarios of designing and constructing a brain surgery clinic. However, each subdiscipline in VADER-2 has an independent virtual environment and mission scenarios, allowing for specific application to second-year AE/C courses. Upon accessing the virtual environment, students begin in a construction trailer, where they receive an overall introduction to the VADER-2 mission from the project manager they have chosen. Subsequently, through the user interface, students can access the independent virtual environments for each discipline to carry out their missions. For example, the virtual environment related to the acoustics discipline was designed as a patient room, enabling students to explore the impact of different door options with varying sound transmission classes on the acoustic condition of the patient room. In the lighting discipline, students engage in a hands-on activity designing the electrical lighting for the clinic's staff office by determining the height and layout of luminaries.

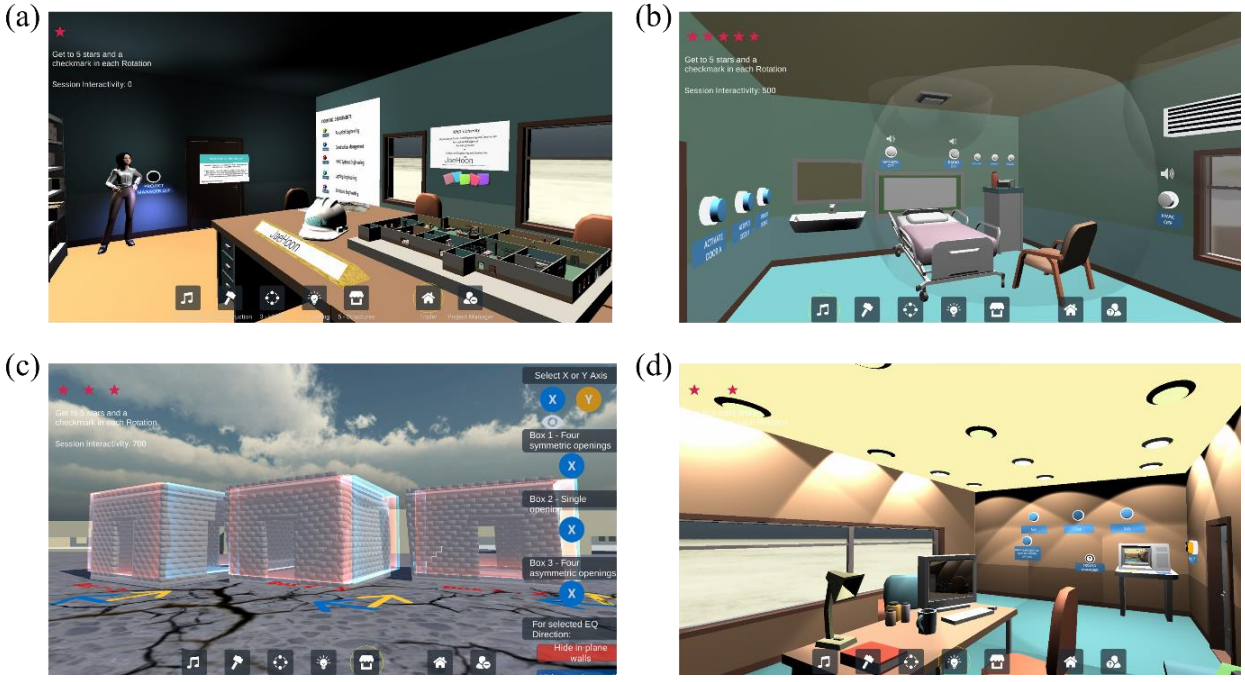

Figure 3. Images of VADER-2: (a) construction trailer, (b) virtual environment for acoustics rotation, (c) virtual environment for structure rotation (d) virtual environment for lighting rotation.

Through discipline-specific virtual environments and mission scenarios, VADER-2 serves as a platform for students to gain fundamental knowledge and practical insights into the five subdisciplines, contributing to their overall development in the AE/C field.

3. Initial implementation of VADER-1 and VADER-2

The initial implementation of VADER-1 and VADER-2 took place in 10 courses across two R1 universities and one HBCU during the Fall semester of 2023, impacting a total of 405 students. In each course, instructors incorporated either VADER-1 or VADER-2 as part of their class assignments. The implementation process was facilitated through Canvas, an online learning management system developed by Instructure, Inc. The Canvas for VADER-1 and VADER-2 included all the necessary content for students to complete their VADER assignments. This content was comprised of a VADER introduction video and documents, lecture slides and videos for each subdiscipline, and links providing access to the virtual environment. In addition, discussion forums to communicate with discipline and technology experts of the VADERs project were incorporated into the Canvas.

As a result of the initial implementation, most students successfully completed VADER modules, indicating the applicability of VADERs within the AE/C program. Important data to evaluate the impact of VADERs were collected, including three reflection surveys aligned with Social Cognitive Career Theory. The reflection survey was administered to students via Qualtrics, an online survey platform, at the beginning of each course and before and after implementing the VADER module. In addition, students' proficiency in VADER learning outcomes was assessed through pre- and post-domain knowledge quizzes managed within Canvas. Each quiz comprised six questions related to the five subdisciplines covered in the VADER module; therefore, it had 30 questions in total. Furthermore, data were gathered from the virtual environment, encompassing students' selection of majors and project managers and time-stamped click-stream data derived from students' interactions within the virtual environment. These data will provide objective insights into student engagement with the VADER modules. The analysis of data obtained from the initial implementation will be presented in a subsequent paper by the research team.

Several challenges and lessons-learned were identified from the initial implementation. Firstly, some students encountered technical issues accessing the VADER modules. For future implementations, specific user guidelines will be developed and distributed to assist students in addressing potential technical issues with using VADER modules. Additionally, managing the submissions of 405 students and tracking their progress in the VADER project using Canvas proved challenging. To improve the deployment of VADER modules across multiple institutions and for larger student bodies, it would be beneficial to create an independent platform dedicated to the VADER project to manage large groups of students from multiple institutions efficiently. Lastly, in the first implementation, it was recognized that instructors play a vital role in promoting student engagement with VADER modules to achieve better learning outcomes.

Therefore, in future implementations, more significant efforts will be made to ensure that instructors fully appreciate the pedagogical value of VADERs.

4. Conclusion

This paper provides an overview of the VADERs project, supported by NSF. Over the first two years of the project, virtual educational modules, namely VADER-1 and VADER-2, were developed to enhance first- and second-year students' engagement in AE/C education. These modules were deployed to 405 students across three institutions during the Fall semester of 2023, generating substantial data for quantitative and qualitative evaluation of the effects of VADER implementations on students' engagement and learning outcomes. In subsequent follow-up studies, the data derived from the initial implementation will be systematically analyzed through a series of statistical analyses. This analysis will, in turn, offer valuable insights for the design and implementation of VR/AR-based educational modules in STEM education. In addition, VADER-R will be developed and implemented, and data from this module's implementation will be analyzed to evaluate its impact on the recruitment of high school and community college students to the AE/C fields.

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