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Immersive Learning Research Network

Work-in-Progress—A CAVE-Based Meteorology Class: From an Instructor's Perspective

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Abstract. Most existing Cave Automatic Virtual Environment (CAVE)-based studies focused on students' learning experiences and outcomes, trying to study how students performed or perceived in a CAVE-based learning process. In this work-in-progress paper, we investigated CAVE's impact on teaching from the instructor's perspective and sought to understand how such a technology might change teaching and what challenges were still there to apply it in the instruction. The initial results indicated that the instructor felt highly satisfied with the ability of CAVE to save them from providing more intuitive visualization to help students understand the learning content. However, the instructor also indicated regret for being unable to apply CAVE in daily teaching due to its size and the difficulties in creating 3D learning content.

Keywords: CAVE, Instructor, Teaching, Perceptions, Challenges.

1 Introduction

Virtual reality (VR) technology has been regarded as helpful in providing educational activities [1]. Previous research studies [2, 3] categorized VR into different types, including text-based VR, desktop-based VR, sensory-immersive VR, and fully immersive VR. Among these VR technology forms, the Cave Automatic Virtual Environment (CAVE) is unusually seen by instructors and learners due to its high cost and complex installation [4].

Though some research studies have explored the impact of CAVE on teaching and learning, they widely investigated from the students' perspective, focusing on students' learning experiences and outcomes [e.g., 5–8]. Many of these studies compared the effectiveness of CAVE on learning with that of other learning media, such as textbooks, 3D animations, or Head-Mounted Display (HMD) VR. Few CAVE researchers, however, investigated the influence of a CAVE learning environment on teaching from the instructors' perspective. We have little knowledge about how instructors perceive CAVE and its impact on teaching effectiveness or experience compared to teaching in a conventional classroom, nor about what challenges or difficulties are observed by them. For example, how do instructors perceive CAVE as a teaching medium? What are the instructors' teaching experience using CAVE? What motivates instructors to use CAVE versus HMD-based VR? What difficulties or challenges would instructors encounter when using CAVE for teaching? How can we optimize the CAVE teaching experience for instructors? We have no ideas about most of these questions.

Therefore, in this preliminary study, we investigated the impact of CAVE on the instructor's teaching effectiveness and experience. We created this class in an undergraduate meteorology course because meteorology challenges instructors' teaching skills to help students visualize (and then understand) various weather phenomena, which is the specialty of a CAVE VR system. The following research questions (RQ) guided our study:

- RQ1: What was the instructor's overall impression of the CAVE VR learning system?
- RQ2: What challenges might hinder the instructor from extensively using the CAVE VR learning system in daily teaching?

2 Literature Review

2.1 Existing Research Using CAVE in Education

A CAVE VR system, configured as a cubic room with digital projectors on its ceiling, projects three-dimensional (3D) visual content onto its walls and floors [4]. Users wear 3D glasses, similar to those used in movie theaters for 3D movies, to immerse themselves in a 3D experience.

Research into the application of CAVE in educational contexts began approximately three decades ago [4]. However, due to its high cost and complex installation requirements, access to CAVE systems for investigating their efficacy in teaching and learning was limited until the last fifteen years. For example, Limniou et al. [8] reported that, compared to students who watched 2D animations, those who experienced learning in the CAVE showed significantly improved learning outcomes and more favorable teacher-student interactions. Similarly, de Back and colleagues [5] found that students in the CAVE group outperformed their textbook counterparts in terms of learning gains. They also observed that, within a CAVE-based learning environment, smaller groups achieved better learning outcomes than larger ones [9].

However, CAVE did not consistently demonstrate superiority over other learning media. According to Leder and colleagues [7], CAVE developed neither short-term nor long-term knowledge retention in students and even led to worse decision-making when compared to HMD VR and PowerPoint slides. In a study conducted by Elor et al. [6], it was HMD VR, not CAVE, that provided a more immersive learning experience with smoother movement and a better emotional state.

These studies primarily center on comparing the effectiveness of CAVE with other media, often assessing learning gains after CAVE training. The majority of research inquiries concentrate on the student perspective, with limited attention given to how CAVE impacted instructors' teaching or how they perceived CAVE as a teaching tool.

2.2 The Development of Teaching Media

The development of teaching media has been a transformative journey, evolving alongside advancements in technology and pedagogical theory. From the days of chalkboards and digitally projected slides to the contemporary use of interactive smartboards and extended reality, the landscape of educational media has expanded dramatically.

In the mid-20th century, teaching media was largely one-dimensional, relying on programmed textbooks and direct instruction using audio recording technology [10]. However, the introduction of film and television into classrooms brought a dynamic new way of presenting information, making learning more engaging and accessible [11]. This visual revolution was followed by the personal computer wave in the late 20th century, which introduced a level of interactivity previously unattainable and supported various forms of learning activities, including lecturing, demonstration, idea sharing, homework revision, and student work promotion [12].

The Internet opened up a world of information, transforming the teaching in the classrooms and empowering teachers with more competencies to teach [13]. The onset of mobile devices such as smartphones and tablets provided teachers with sufficient learning resources but also demanded new teaching strategies [14]. The rise of e-learning democratized education, making it possible for anyone with an Internet connection to access courses from institutions around the world [15, 16] and thus transformed the role of teachers in a conventional teaching context [17]. Meanwhile, educators began harnessing social media as a tool for teaching, creating communities of learning and expanding classroom discussions into the digital sphere [18].

Nowadays, VR, augmented reality (AR), and mixed reality (MR) offer novel and experiential learning opportunities that once only existed in science fiction. Teachers and instructors can provide vivid and intuitive classes for students and enhance their learning experience and outcomes using VR [19], AR [20], and MR [21].

The continual development of teaching media is not without challenges. Issues such as teachers' resistance to using new teaching media [11, 22] or their biases in accepting new technologies as appropriate teaching tools [23] may retard the application and spread of new teaching media in classrooms.

2.3 Using TPACK to Guide VR-Enabled Learning

While integrating various technologies into teaching, researchers frequently used the Technological Pedagogical Content Knowledge (TPACK) model as a theoretical framework. In recent years, this model has been used to yield new perspectives and teaching methods when integrated with VR technology [24]. For example, previous researchers found that, guided by the TPACK model, the instructors could facilitate students' deep learning and enhance the latter's learning interests, engagement, motivation, and autonomy in a VRLE [25]. Other researchers used the model to create determination heuristics regarding the necessity of applying VR in K-12 and higher education classes [26]. Despite a wide claim that VR could be helpful to learning, many teachers, including pre-service teachers, actually had little knowledge, skills, or experience in using VR as a teaching tool [27].

3 Methodology

This study aimed to understand how the instructor perceived CAVE as a teaching tool in a meteorology class. We adopt the TPACK model as our theoretical framework. As a professional development model, TPACK outlines the essential knowledge that instructors need to possess when integrating technologies into their teaching or instruction practices [28]. According to this model, an instructor who wants to incorporate technology into their classroom is expected to acquire three types of knowledge: Technological knowledge, pedagogical knowledge, and content knowledge [29]. In our study, the instructor possessed (1) content knowledge—knowledge about meteorology, especially about the mid-latitude cyclones in North America; (2) pedagogical knowledge—knowledge about how to organize and implement learning activities in classes; and (3) technological knowledge—the instructor was well trained how to use the CAVE system before engaging the students in the CAVE-VR-based class.

3.1 Participants

In this preliminary study, we recruited one instructor and 21 students from a meteorology program at a mid-western R1 university. The instructor was a white/Caucasian male in his 40s. By the time of this study, the instructor had been teaching the same course content for more than five semesters. He usually taught with slides created in MS PowerPoint, supplemented his teaching with 2D or 3D pictures, videos, or animations of maps or meteorological events, and had never experienced any type of VR-enable teaching. The students were from the instructor's class. They were assigned into four groups, each with 4 to 6 students, to accommodate the capacity of the CAVE room.

3.2 The Design of the CAVE VR Learning System

On the hardware end, we used a VisCube M4 CAVE system produced by Visbox [30]. The screen sizes for the front wall and the floor are 140'' x 87.5'' with a resolution of 1920 x 1200. The screen sizes for the two side walls are 94'' x 87.5'' with a resolution of 1280 x 1200 (see Fig. 1). There is no back wall in the M4 CAVE system, so we used a black curtain to close the room and keep it immersive. This CAVE system comes with an active stereo, one controller, and 10 pairs of glasses.

Fig. 1. Our CAVE system with three walls and one floor.

On the software end, we created our VR world using Unity3D, based on the map of the continuous 48 states of the United States. We chose a topic—the middle-latitude cyclone—in meteorology as our major learning content because both the instructor and students believed that this topic was difficult to teach or learn without an appropriate visualization of the learning content in their minds. In the VR world, there were arrows showing the directions of cyclones above the U.S. continent, different colors of belts indicating the cold and warm fronts, and pop-up windows displaying the elevation of the player's current location. Users could teleport themselves from one location to another using the joint stick to view the cyclones in different directions and elevations. We also created special weather effects, such as clouds, sunshine, rain, snow, and storms at different locations on the map and the corresponding sound effects, such as wind, rain, snow, lightning, and thunder. Fig 2 and Fig 3 show what the CAVE VR learning environment looks like.

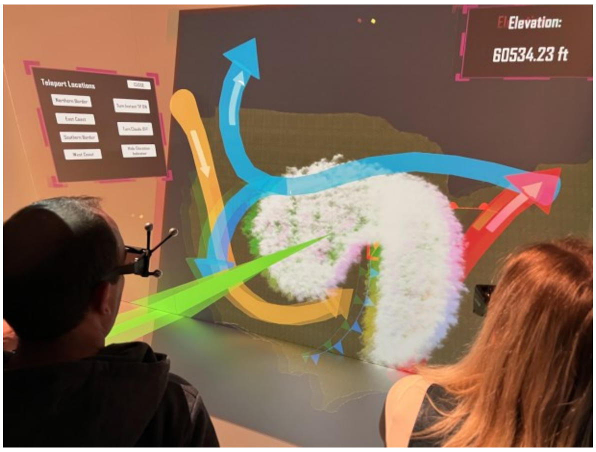

Fig. 2. Our CAVE-based VR world included arrows showing the directions of cyclones above the U.S. continent, belts indicating the cold and warm fronts, and some weather special effects such as clouds.

Fig. 3. Our CAVE-based VR world included weather special effects such as clouds, sunshine, rain, snow, and storm and the corresponding sound effects such as wind, raining, snowing, lightning, and thundering.

3.3 Data Collection

This study is still ongoing. Due to the time and technology needed to create a specific learning environment for an individual instructor, we planned multiple rounds of data collection. The first round of data collection was in the spring semester of 2023. The instructor delivered the class through identical teaching sequences and learning activities to all four student groups. Students listened to the instructor's explanation, watched the instructor's demonstration, and discussed with group members the learning task. After the class, the instructor was interviewed immediately regarding his perceptions of the CAVE VR learning system and the teaching experience in this system. The interview was audio-recorded for data analysis purposes.

3.4 Data Analysis

We transcribed the instructor's interview recordings into text. Since we had only one instructor so far and the study was still in progress, we did not apply any formal qualitative data analysis such as narrative analysis or thematic analysis. Instead, we browsed the instructor's interview transcript and extracted key information that could answer our RQs.

4 Results

4.1 RQ1: What Was the Instructor's Overall Impression of the CAVE VR Learning System?

The instructor's overall impression of the CAVE VR learning system was very positive. The instructor indicated that he could not spot any negative things about the CAVE-enabled class. He was particularly satisfied with the 3D visualization feature offered by the CAVE VR learning system, "*It was helpful for me to explain the 3D objects that you just can't do in a traditional classroom setting.*"

The instructor believed that the CAVE-enabled class helped students immerse and engage themselves in the class. He was amazed to see his students actively participate and collaborate in the class activities. He compared how students behaved in the conventional classroom and the CAVE-enabled class and affirmed that students were more engaged in the latter than in the former, "*[In the conventional classroom,] they're sitting, taking notes, listening, whereas here, they're standing there and interacting; they're asking questions; they're collaborating; they're able to point through and able to visualize. It's not the same experience as in a regular classroom.*"

4.2 RQ2: What Challenges Might Hinder the Instructor from Extensively Using the CAVE VR Learning System in Daily Teaching?

As for the challenges, the instructor believed that the current CAVE VR learning system was too large to fit a regular classroom size. To perform a CAVE-enabled class, he had to "*walk across the campus*" to the lab where the CAVE system was located. Meanwhile, the instructor also reported that the existing CAVE room was too small for him and all students to be present at the same time. He had to teach the same content four times.

In addition, the technological requirements for creating 3D content in the CAVE VR learning system might limit an instructor to use it. During the class in CAVE, ideas of creating various 3D objects or interactions kept popping up in the instructor's mind, "*As we went through this and that, I thought, 'Oh, this would have been great to have it here or this would have been great to add there.'*" With little knowledge of 3D modeling, game development, and programming, however, the instructor admitted, "*I don't know how to program any of that.*" Obviously, the instructor alone could not provide the 3D learning content for his students in the CAVE-enabled class, even if the CAVE system could be moved to his regular classroom.

5 Discussion

5.1 RQ1: What Was the Instructor's Overall Impression of the CAVE VR Learning System?

Though the TPACK model does not take teachers' beliefs in the effectiveness of technology into consideration [31], the instructor in our study demonstrated a strong confidence in the role the CAVE VR learning system could play in his teaching. The CAVE VR learning system saved the instructor's cognitive efforts to visualize meteorological events in a 3D representation. The instructor was liberated from the chores of creating 3D visualization for students so that he could focus on delivering the learning content, organizing the class activities, explaining important meteorological concepts and procedures to students, and motivating them to engage in the class better.

Since we have only one instructor as our participant, we did not notice any resistance from him about teaching with CAVE. This observation was different from what some previous researchers claimed [11, 22]. However, in previous research about teachers' resistance to technology use in classrooms, the researchers investigated the issue among teachers of various ages and teaching experiences. Therefore, we might notice teachers' resistance to adopting a new technology like CAVE if we could include more instructors as our participants.

5.2 RQ2: What Challenges Might Hinder the Instructor from Extensively Using the CAVE VR Learning System in Daily Teaching?

The instructor identified several challenges when using the CAVE VR learning system for daily teaching. First, they noted that the size of the CAVE was too large. However, this large size posed a contradictory challenge because it was simultaneously too small to accommodate more students. This seemingly conflicting assessment highlights a dual-sided issue with the current CAVE VR learning system.

On the one hand, the CAVE is not designed for portability, making it impractical for installation in a standard classroom, where instructors expect to use CAVE as they use projector screens or smart boards. On the other hand, the CAVE has limitations in accommodating a larger audience simultaneously, which is a concern for instructors who wish to have more students view 3D visualized meteorology events simultaneously.

Furthermore, the instructor expressed doubt about his ability to create 3D meteorological event presentations or interactive VR environments, which is required as the technological knowledge (and skills) in the TPACK framework [29]. Such doubts, if left unaddressed, could potentially lead to resistance to using technology in the classroom. While our participants did not exhibit resistance, previous researchers have studied and discussed this phenomenon, emphasizing that factors such as technological skills, access to learning resources, and adequate support significantly impact instructors' self-efficacy in acquiring new skills [32, 33].

While providing skill training is an option for instructors, it is important to acknowledge that they might not have the time to undergo comprehensive training to master a complex system such as a VR building platform or a game engine. Therefore, to enable instructors to effortlessly create 3D VR scenarios, we believe that the most helpful solution is to simplify existing 3D modeling and VR building systems and lower their technological barriers. This endeavor will enable instructors to craft VR learning environments with the same ease as creating PowerPoint slides.

6 Conclusion

This preliminary study examined how the instructor perceived the impact of a CAVE-enabled class on their class delivery. Though we found that the instructor was satisfied with the CAVE VR learning system as a teaching medium, some challenges might hamper the instructors from using CAVE in a normal classroom, at least in the short term. As we mentioned in the introduction of this paper, very few previous studies have explored instructors' teaching experiences and effectiveness using CAVE. Since we have only one instructor by now, we may not answer many questions right away. That is why we plan to invite more instructors to use CAVE for teaching. We hope to find answers from multiple instructors with CAVE teaching experiences.

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