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PAPER

Enhancing Collaborative Learning in Mobile Environments through Interactive Virtual Reality Simulations

Rijal Abdullah[1], Mohd Nasrun Mohd Nawi[2](✉), Anas A. Salameh[3], Rafikullah Deraman[4], Aizul Nahar Harun[5]

[1]Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia

[2]Disaster Management of Institute (DMI), School of Technology Management and Logistics, Universiti Utara Malaysia, Kedah, Malaysia

[3]Department of Management Information Systems, College of Business Administration, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia

[4]Project and Facilities Management Research Group, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Malaysia

[5]YU-MJIIT International Joint Intellectual Property Lab (YU-MJIIT IJIPL), Department of Management of Technology, Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia

nasrun@uum.edu.my

ABSTRACT

This study investigates the potential of enhancing collaborative learning in mobile environments through the integration of interactive virtual reality (VR) simulations. With the ubiquity of mobile devices and advancements in VR technology, there is a growing interest in using immersive experiences to promote collaborative learning among students. The study explores the design and implementation of interactive VR simulations customized for mobile platforms. The goal is to create engaging and immersive learning experiences that foster collaboration and knowledge sharing. By immersing students in virtual environments where they can interact with digital objects and manipulate scenarios, the study aims to facilitate active participation and teamwork, thereby enhancing learning outcomes. Furthermore, the study examines the impact of interactive VR simulations on student engagement, motivation, and knowledge retention in collaborative learning settings. Through empirical studies and user evaluations, the effectiveness of interactive VR simulations as a tool for collaborative learning in mobile environments is assessed. The findings provide valuable insights into the design and pedagogical integration of VR technologies in mobile learning contexts. They offer guidance for educators and instructional designers who aim to leverage the potential of immersive experiences to improve collaborative learning outcomes.

KEYWORDS

collaborative learning, virtual reality (VR), mobile environments, knowledge sharing, student engagement

1 INTRODUCTION

Individuals using unique electronic devices, such as headgear with an internal screen or mittens with sensors, can interact with an almost real or physical image or environment through virtual reality (VR), as defined by the online Oxford dictionary.

Despite having its origins in the 19th century, when the first 360-degree paintings in the form of panoramic murals started to appear, the phrase was first used

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in the 1960s. Slightly over a century later, the Sensorama, a mechanical apparatus, combined multiple senses to offer an immersive VR experience. Since then, VR has changed in several ways, becoming increasingly similar to the real world [1]. ICT and VR are now intrinsically connected, and HCIs are becoming more extensive and adaptable as processing power increases.

A commonly used term in VR is "immersion." This term broadly refers to becoming so engrossed in a game that one loses track of time and the outside world while still feeling fully immersed in the task at hand. The term "immersion" in VR typically refers to "spatial involvement," which is a narrower definition. There has been a debate over whether VR can revolutionize education for decades.

It is asserted that VR has uses in simulation-based education, providing students and learners with access to costly or distant locations. This technology allows them to practice new skills in a controlled environment that allows for adjustments, repetition, and safe failure. Despite high hopes, these ideas have proven to be more theoretical than practical. VR technology is still not developed enough to be applied to training and general education outside of specialty simulators for medical professionals, flight attendants, and members of the armed forces. But all of that changed in 2013, when the first developer versions of the Oculus Rift headset were made available, ushering in a new era of VR technology that was also accessible for retail purchase. Similar VR devices from 2006 and 2014, which cost USD 45,000 and USD 1,300, respectively, opened up this innovative technology to the general public, academics, and educators. Several competitors introduced their head-mounted displays (HMDs) over the next few years. VR technologies are expected to be implemented in the higher education sector within two to three years, according to a 2016 assessment by the New Media Consortium on technological advancements in higher education.

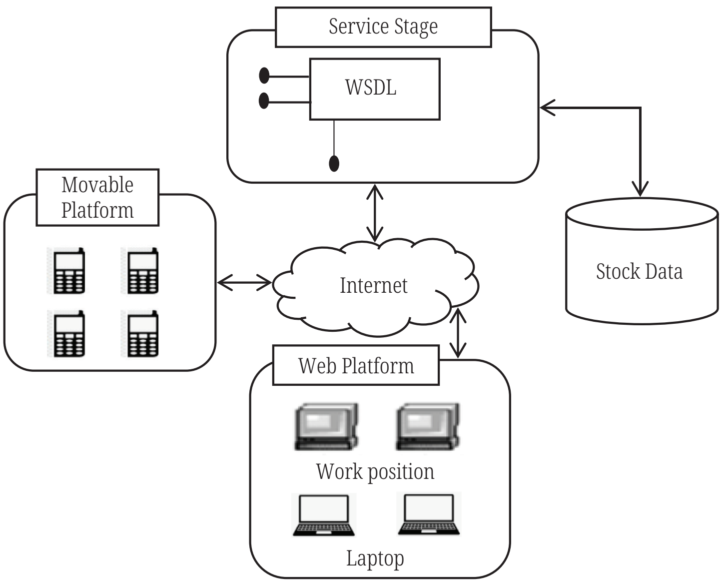

Fig. 1. Design of m-learning application

Furthermore, VR has been dubbed the 21st century's learning aid. According to a study, after participating in VR workouts, students can retain more information and apply it more effectively. Given the potential for enhancing learning through VR use, it is logical that organizations, academics, and educators are already closely scrutinizing this technology to offer a distinctive perspective on classroom education and instruction.

A few comprehensive summaries and systematic mappings of VR applications for education already exist due to the increasing scholarly interest in VR technologies (see Figure 1). For instance, Jensen and Konradsen emphasize the use of HMD technology and focus on desktop VR in teaching [3]. Although Jensen and Konradsen's focus on learning outcomes and experiences aligns with this review, they do not specify their target audience. Moreover, neither of these two studies examines the fundamental ideas about learning that inform the development of VR applications or their design elements.

This is the outline of the work: Section 2 presents relevant literature on systematic reviews of VR in an educational setting.

An analysis of the gaps and a description of how our work fills them are presented in the conclusion of this section. In Section 3, we explain our study design, semi-automated filtering method, analysis techniques, and literature identification search process. There are four analysis frameworks in Section 4. The implications, potential for future research recommendations for educators, and constraints of our work are emphasized. Finally, in Section 5, we present our conclusion.

2 LITERATURE REVIEW

[4] The present design research study follows the development of environmental detectives through four field trials, from early conception to the initial attempts at creating a set of game development tools for augmented reality (AR) game production. It does this by using a design narrative. Studies on other emerging technologies, such as the car, suggest that case studies focusing on user behavior could be a valuable tool for understanding new technology. This software development process draws inspiration from rapid prototyping methodologies, where designers create multiple disposable programs to test the accessibility and educational value of specific functions and hypotheses instead of outlining a set of features and then constructing a robust platform from the ground up.

According to [5], video games have the special ability to foster, activate, and recruit an awareness of projective identity, which acts as a bridge between students' virtual or game identities and their real-world identities. Students develop simulation or game identities within gaming settings, where objectives and morals align with and shape their real-world identities. The virtual identities can then be used to influence and mold the ongoing evolution of real-world identities if learners embrace and take responsibility for them. In a similar vein, we developed outdoor augmented reality simulations utilizing mobile computers and GPS equipment. Nevertheless, we have developed a location-independent AR simulation that can be situated in any real space instead of being dependent on a specific location.

[6] Trainers sometimes make the error of believing that performance can only be enhanced by high-fidelity simulations. This is untrue, as the aforementioned Yale VR-to-OR study amply illustrates. Should we be asking whether the simulator teaches the necessary skills to perform the procedure? It should be mentioned that prices increase in line with loyalty. The VIST structure, which replicates a complete physics simulation of the vascular system in real-time, is one of the most advanced VR simulators available today. Nevertheless, each unit costs $300,000. Not every training program can afford to simulate to this extent.

[7] Virtual reality education is becoming increasingly popular in the field of spatial aptitude studies. Spatial activities encounter the visual challenge of representing a 3D task through a 2D medium, along with difficulties related to inspiration

and engagement. While students may find standard paper-and-pencil exercises boring or uninspiring, using VR to introduce spatial training challenges may help enhance learners' motivation. In recent years, a large number of researchers have been exploring innovative media, such as VR and AR, as solutions for spatial training challenges. One method involves having users rotate shapes in an online setting to improve their mental rotation skills. In another instance, the virtual world was enhanced with visual cues to assist in mental rotation retraining.

[8] Through increased physical interaction with peers facilitated by mobile devices, students' coordination and engagement in computer-supported cooperative learning are enhanced. Students can engage more naturally with their peers due to their mobility. To promote peer cooperation and the creation of new knowledge, facilitating physical touch and interaction would be advantageous. While using mobile devices, students have the freedom to travel around the world and be untethered from their computers. With the increase in the use of mobile devices, there are more opportunities for users to explore the real world further.

[9] Many e-learning scenarios could benefit from a useful cooperation tool to support their implementation. As long as the setting satisfies their functional needs, e-learning scenarios can incorporate one or more teaching methods, such as role-playing, case studies, collaborative endeavors, idea generation, jigsaw, and many more. Croquet can handle a wide range of collaborative learning situations due to its ability to interact with objects, text, and voice communications. Many tools have been developed or could be developed. The absence of programmer collaboration is undoubtedly a problem that needs to be addressed, although the shared text editor and whiteboard can both help in this regard.

3 METHODS AND MATERIALS

3.1 VR immersion on a mobile device

The sensation of truly being present in a computer-generated virtual environment is the essence of immersion. With the development of VR equipment such as head-mounted displays and tracked controls, the mobile VR world can create more immersive experiences than the current computer-based environment. In addition to visual, aural, and tactile signals, other factors that contribute to VR immersion include system latency [10], content richness, stereo cues, and the behavioral realism of the simulated environment. Due to its low power, mobile VR is particularly sensitive to factors such as latency and resolution. As a result, while maintaining low computational resource consumption, factors such as visual quality, audio quality, and intuitive interactions can be taken into consideration to enhance the immersive experience on mobile devices in VR. Several methods have been proposed to synchronize the virtual and real worlds in order to enhance user interaction and immersion in mobile VR. These methods enable users to navigate the virtual world by mapping their movements in the physical space to the virtual environment. Furthermore, interactive devices that can recognize hand gestures have been developed. Despite this, there is a lack of research focusing on enhancing 3D audio or visual performance for portable VR systems.

Quantification of immersion experiences. For a long time, particularly in the gaming industry, researchers have been exploring methods to evaluate immersion in online environments. Gamers' engagement with games has been extensively measured through the use of GEQ. A more precise technique for measuring immersion in an online environment has just been released. The questionnaire's reliability is demonstrated by 87 questions and 10 rating scales [11]. We validate the effectiveness of our framework by assessing the aspects of flow, immersion, vitality, emotions, and judgment using the ten provided scales.

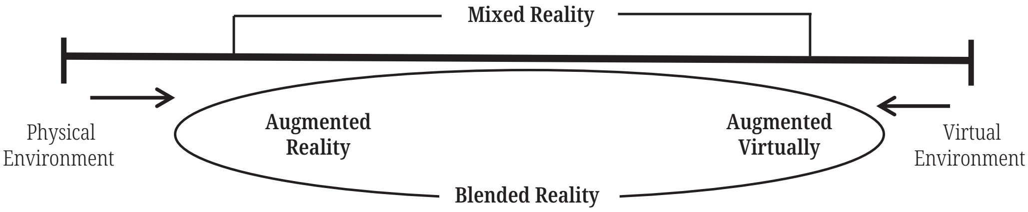

Fig. 2. Mixed realities in connection to the continuum of the actual and virtual environments

The study investigated the use of a three-dimensional (3D) virtual world, also known as a 3D multi-user virtual environment (MUVE), as shown in Figure 2, to establish a mixed reality collaborative setting in a pre-service teacher education course at an Australian university. Students positioned remotely could see and hear the teacher through a live video feed in the virtual world, while students in the classroom could see and hear their remote peers through a virtual world projection on the wall. An analysis was conducted on the educational, technological, and logistical elements that impacted the students' experience. Specifically, the research was framed and led by the following overarching question:

What logistical, educational, and technological factors support or impede the implementation of collaborative learning environments based on blended reality for tutorial classes in higher education settings?

By employing a qualitative analysis of student perspectives, the research problem was investigated, and the impact of the approach on co-presence, interaction, and collaboration was assessed.

3.2 Design and technological setup of a virtual learning environment

The primary virtual world room featured a central conference room for gatherings, a few smaller "break-out" or satellite rooms outside the main room where pupils could take notes and prepare for group work assignments, and three pupil computer monitors that projected the IWB, other instructional content, and the live video feed of the F2F class onto the walls so that students who were located remotely could see what was happening in the real classroom instruction.

Three-note spaces connected to boards in the breakout rooms were also set up on the side walls of the main virtual world room. This allowed students who were not present physically to access and review all group work responses in a centralized location.

The video stream from the streaming server needs to be integrated into a webpage using a Flow Player plugin to display the in-world perspective of the F2F class (see Figure 3). The webpage was then displayed in the corresponding virtual world area. The video feed from the face-to-face classroom was delayed by about seven seconds due to the slight lag caused by each of the equipment's components [13]. The PCs that the student teams were using for their work were logged into three avatars. The virtual world's screen-sharing function was utilized to stream specific F2F student workstations into the virtual environment.

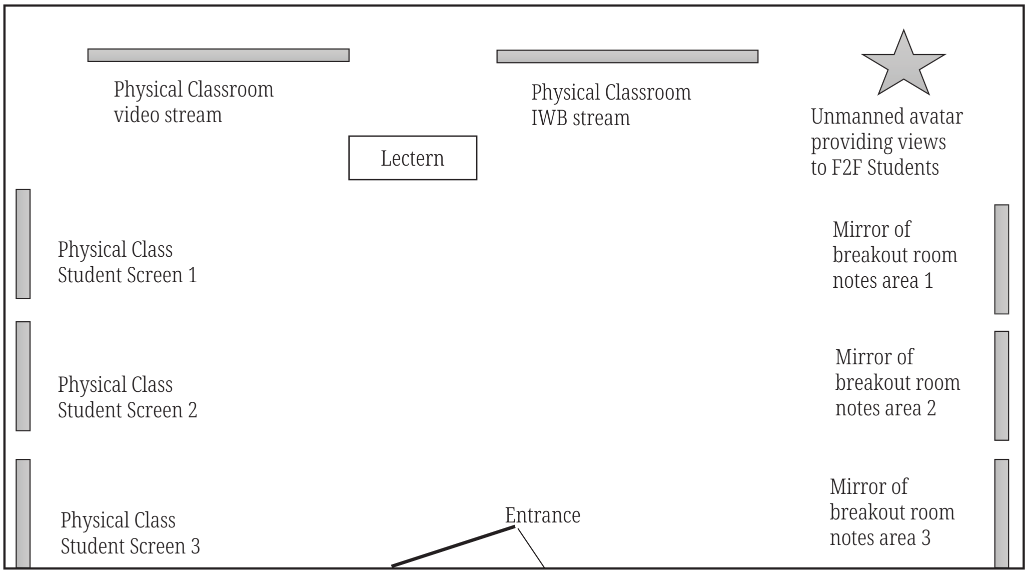

Fig. 3. Design and look of the virtual world's main chamber

A built-in feature of the online system that allowed note sections to be shown by name was used to connect the separate rooms' note areas to the main room's displays. The lesson plan aimed to investigate the potential of blended reality settings for supporting student-centered group work, instructor instruction, and guided discussions. The course material was reviewed by the teacher in a brief slide-supported presentation that kicked off the session. A brief introduction was provided to the concepts of blended realities and blended asynchronous learning. Following that, a class discussion exercise was conducted. Remote students who participated virtually and face-to-face students in the physical classroom were asked to stand on floor markers placed in their respective settings. They indicated how relevant and helpful they believed online worlds were for educational purposes. The teacher then asked a few students in each group to justify their perceptions, which sparked a discussion among the entire class.

In a second group activity, students were assigned the same task: to create a captivating lesson plan utilizing virtual environments and essential teaching methods to guarantee its success. Students wrote about their views using the same format as the previous homework. During the meeting, each group's lesson plan was discussed, and afterward, all the children raised their hands to show which proposal they believed was the best. The team with the most votes received a meager prize. Participants were asked to reposition themselves along the floor markers in a concluding self-reflection activity to indicate how they felt about the educational value of virtual environments. They discussed whether their views had shifted since the beginning of the course and, if so, why.

4 IMPLEMENTATION AND EXPERIMENTAL RESULTS

When participants first arrived at the lab, they had to fill out a pretest questionnaire evaluating their knowledge of science, specifically focusing on the solar system. Respondents were randomly assigned to read one of two articles on gender disparity and technological advances as part of a larger study. One article claimed that women are equally adept at utilizing computers as men, while the other indicated that men perform better in this area. Since it did not appear to have an effect on the study's outcome variables, we have chosen not to disclose this modification in our findings [14]. An analysis of whether the modification affected people's sense of acceptance and belonging to gender norms in STEM professions will be included in a later article.

Table 1. For the outcome factors (N = 209) the mean, standard deviation, and t-tests

Variables	Virtual Reality (n = 52)		Augmented Reality (n = 57)		t – Test (df = 107)	
	M	SD	M	SD	*t*	*P – Value*
Attention	6.12	0.79	5.79	0.91	2.05	0.044*
Presence	4.34	1.17	1.17	1.26	4.80	0.000***
Enjoyment	3.80	0.85	0.85	1.91	1.89	0.064
Science knowledge (pretest)	5.60	1.56	1.56	1.67	1.52	0.136
Auditory Knowledge (posttest)	6.52	3.06	3.06	2.50	2.29	0.025*
Visual knowledge (posttest)	3.90	2.14	2.14	2.14	2.08	0.042*

This study evaluated how AR and VR affected the ability of cellphone platforms to retain the information presented in Table 1.

Compared to those in the AR condition, individuals in the VR control reported higher levels of satisfaction, felt a greater sense of spatial presence, and focused more attention on the simulated world. In other words, compared to the AR scenario, being in the VR condition triggered stronger emotional and cognitive responses to the media. Furthermore, participants retained more information when it was presented visually in the mobile app, thanks to the emotional and cognitive reactions elicited by the media. In contrast to those in the VR condition, individuals in the AR condition remembered more auditory-related science information even when they retained less visual-related science information. The relationship between modality and learning about science was influenced by the participants' sense of spatial presence. More precisely, by emphasizing the visual aspects of the controlled environment, participants in the VR condition received more detailed information in the visual modality and less in the auditory modality. This finding is consistent with previous research on the cooperative attention capacity between visual and auditory stimuli.

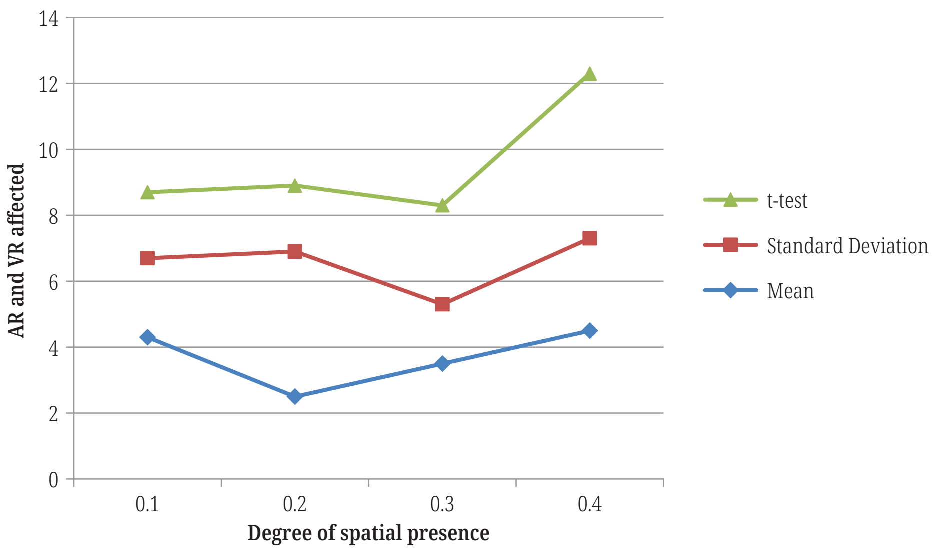

Fig. 4. The outcome factors (N = 209) the mean, standard deviation, and t-tests

As a result of their reduced cognitive and psychological reactions to the virtual environment (see Figure 4), individuals in the AR condition were able to focus more of their attention and cognitive resources on remembering the aural information. The effects of VR and AR technologies on participants' ratings for aural information were explained by the degree of spatial presence, but not for visual information. This surprising result suggests that further investigation into the connection between spatial presence and learning in these two media modalities is warranted. This research suggests that users' cognitive needs for AR and VR vary, which has significant theoretical implications for the literature on these two modalities. Specifically, it appears that VR is more captivating and immersive due to the psychological concept of spatial presence. However, considering the cognitive demands of these immersive experiences, AR might be a more suitable medium for conveying non-visual (or audio) information.

It is important for researchers to continue investigating the cognitive and behavioral distinctions between these two media modes.

The implications of these findings are significant for educators as well as for interaction media, technology architects, and developers. As VR emphasizes the visual data available in the environment, it seems like a better tool for instructors who wish to highlight visually communicated content. AR, on the other hand, appears to be more effective when digital educational tools contain significant information that is communicated through auditory channels. This is because it frees up attention and cognitive resources that would otherwise be allocated to visual channels, enabling auditory data to be processed more deeply.

Creators of instructional VR and AR applications should consider the cognitive demands and frameworks that are most suitable for various types of content. When designing VR experiences, it could be beneficial to integrate relevant information visibly into the surroundings. Similarly, when creating AR experiences, it might be ideal to convey relevant information through audio.

4.1 Restrictions and upcoming studies

There are several restrictions on this study. A sample of college-age individuals, predominantly female, was used in the study. Future researchers should enhance the representativeness of the population samples they use to improve the generalizability of their findings.

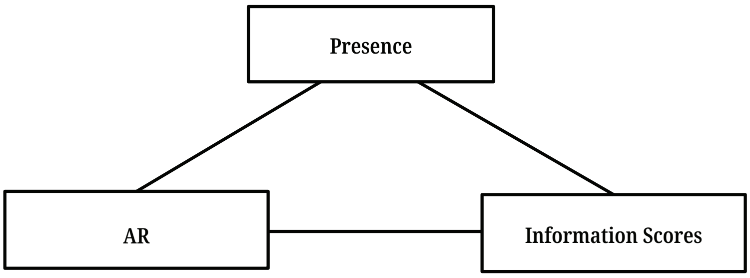

Fig. 5. Coefficients of standardized analysis for the presence-mediated link between AR and auditory information scores

Only self-reported questions were used in the study to assess participants' perceptions of their spatial presence (see Figure 5). Non-disruptive, in-situ measurements should be included in future studies to reliably confirm and corroborate the impact on participants' sense of presence. Although there is a correlation between the two variables, this study primarily focused on attention resources rather than cognitive burden. The attention load measurement does not always accurately reflect the participants' perceptual load. Future studies should examine in more detail how people's emotions, existence, and educational outcomes are affected by cognitive or perceptual workload when using these two technologies. Future research should consider data concreteness as a potential confounding factor between modalities, as the auditory information provided in the application was probably more abstract than the visually presented data. The study could not account for the fact that many participants may have had no prior experience with AR and VR technologies [15, 16]. Future studies should investigate whether a person's previous experience with these tools influences the effectiveness of AR and VR in educational settings. Future studies should also examine whether learning outcomes across different modes are influenced by [17], or even optimized by, the consistency of audio and video content or the types of auditory output.

5 CONCLUSIONS

The m-learning system proves to be the most practical option as the number of classrooms facing network outages continues to increase. Because it has audio and video functionality, this system is suitable for distributed multimedia classrooms. The system incorporates various forms of communication, question-and-answer sessions, multiple learning sessions, high levels of efficiency and cooperation, low levels of recurring costs, and time constraints. With the help of this system, students can receive support in the areas of consistency, ease, immediacy, interaction, situational awareness, and adaptation. To encourage students to use the system for their learning, it must have an intuitive user interface.

Both affordable and transportable, there is massive educational potential with VR technologies through smartphone-based mobile apps. It could alter how students engage with science content if VR could take them to the stars or if AR could build a solar system on their desktops. Research has demonstrated that science-based content can be effectively taught via AR and VR. Nonetheless, when incorporating AR and VR into educational settings, it's important to consider their unique advantages and disadvantages. Ultimately, these technological advancements offer students an innovative and stimulating form of instruction.

Some activities require extensive planning, like a lengthy project, while others need less, such as inviting students to debate their ideas with their neighbors or asking a question during a lecture. The objective is always the same: to shift the learning paradigm from being teacher-centered to being student-centered, irrespective of the specific strategy employed or the degree to which the traditional lecture-based course is substituted. The goal of this system is to enhance a collaborative learning environment for students, enabling them to complete their coursework more efficiently.

6 FUNDING STATEMENT

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8 AUTHORS

Dr. Rijal Abdullah works as a Lecturer at the Faculty of Engineering, Padang State University. The author is active in writing articles in the fields of engineering and education (E-mail: rijal_a@ft.unp.ac.id).

Mohd Nasrun Mohd Nawi specializes in the area of integrated design and construction management. He holds a PhD in the field of Construction Project Management from the University of Salford, UK. As an academic and a fully qualified Building Surveyor, he has been actively involved in research and consulting work related to the areas of Industrialized (offsite) and Modern Methods of Construction, as well as Integrated Design Delivery Solutions. Integrated Project Delivery, Lean Construction, Building Information Modelling, Sustainable (Green) Construction, Life Cycle Costing, Value Management, Building Performance (e.g., Energy Management and Audit), and Management of Technology. Besides actively particularly in various academic activities, he is also a prolific author with numerous publications, particularly in the field of Construction and Technology Management (E-mail: nasrun@uum.edu.my).

Dr. Anas A. Salameh is an Associate Professor in the Department of Management Information Systems at the College of Business Administration, Prince Sattam Bin Abdulaziz University. He has held this position since 2016. Additionally, he serves as the current deputy director of the students' activities committee and is a member of the exams scheduling committee at PSAU. His major research interests focus on areas such as e-commerce (m-commerce), e-business, e-marketing, technology acceptance/adoption, e-learning, e-CRM, and service quality. He has evaluated service quality in various areas related to e-services (E-mail: a.salameh@psau.edu.sa).

Ts. Dr. Rafikullah Deraman is a Senior Lecturer at the Department of Architecture, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn, Malaysia. He also serves as the Head of the Accreditation Department for Academic Development (CAD) at Universiti Tun Hussein Onn, Malaysia. He graduated with a PhD in Construction IT from the University of Malaya in 2014. He is also a professional technologist registered with the Malaysia Board of Technologists (MBOT) since 2017. He has almost 4.5 years of industrial working experience and 24 years of experience with educational institutions. He has been a certified internal lead auditor for UTHM since 2017 and a member of the accreditation audit panel for the Technology and Technical Accreditation Council (TTAC, MBOT) since 2020. He has

been reviewing various international journal papers and serving as the program advisor for undergraduate programs at INTI International University. His research interests mainly include sustainable building materials, construction IT, construction management, and building maintenance (E-mail: rafikullah@uthm.edu.my).

Aizul Nahar Harun is a Senior Lecturer specializing in Built Environment at Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia. Until May 2009, for nine years, he managed property projects in the housing, manufacturing, and tourism sectors. This includes the activities of identifying, developing, and managing feasibility studies and project phasing/implementation plans, formulating of the land development strategies, and overseeing environmental risk assessment and management plans for identified projects. He earned his B.Sc (Hons) from Universiti Teknologi Malaysia, M.Sc from Universiti Teknologi MARA, and his PhD from the University of Salford, United Kingdom. Since May 2009, he has been working as academic staff. His area of research interest includes the Internet of Things, Environmental Management Systems, Building Information Modelling, and Sustainable Development (E-mail: aizulnahar.kl@utm.my).