AUGMENTED REALITY AND 4D MODELING IN HIGHER EDUCATION

Vuk Čvorović*,
[0009-0004-5278-3673]
Marija Jovanović
[0009-0001-8934-6571]

Singidunum University,
Belgrade, Serbia

Abstract:

This paper explores the potential of Augmented Reality (AR) and 4D modeling to transform higher education. As technology continues to advance, educators are increasingly leveraging AR and 4D modeling to enhance teaching, learning, research, and campus management. It delves into the fundamental concepts of AR and 4D modelling through literature review, examines their applications across various educational domains through real-world examples, and discusses the benefits and challenges associated with their integration into higher education. It also shows how application of this technology affects students' performance and assignment results and what benefits they might have in terms of better understanding of complex spatial concepts.

Keywords:

Augmented Reality, 4D Modeling, Higher Education.

INTRODUCTION

Augmented Reality (AR) and 4D modeling have already found its place in higher education [1]. Students apply this technology in their every-day activities through different kind of software and hardware [2]. For example, Google has recently introduced latest version of its AR/VR headset (Meta Quest 3) which uses Oculus software to communicate with PC (to connect the device to PC, upload files to headset, etc.) [3]. Oculus software is used as file type converter, since AR/VR sets use specific file format, so students can create their models in any 3D software (e.g. Autodesk Revit) and then simple convert it and evaluate it on AR/VR set, as will be illustrated in Application segment of this paper.

1.1. AUGMENTED REALITY

Augmented Reality (AR) is a technology that superimposes digital information, such as images, sounds, or text, onto the real-world environment to improve the user's perception and interaction with the surroundings. Unlike virtual reality, which creates a completely immersive digital environment, AR integrates virtual elements into the existing

Correspondence:
Vuk Čvorović

e-mail:
vuk.cvorovic.22@singimail.rs

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physical environment. AR is typically experienced through devices like smartphones, tablets, smart glasses, or AR-specific hardware. [4]

One of the fundamental aspects of AR is its ability to blend the virtual and real worlds seamlessly. This is achieved through computer vision, sensors, and advanced algorithms that recognize and track the user's environment in real-time. AR applications vary across industries, including gaming, education, healthcare, manufacturing, and marketing. For instance, AR can be used in navigation apps to display real-time directions on a smartphone screen or in educational settings to provide interactive learning experiences by overlaying information onto textbooks.

As technology advances, AR continues to evolve, offering more sophisticated and immersive experiences. The potential applications of AR are vast, ranging from entertainment and gaming to practical business solutions like remote assistance, training simulations, and product visualization.

1.2. 4D MODELING

4D modeling is an extension of 3D modeling that incorporates the element of time, adding the fourth dimension to the spatial representation. In the context of construction and project management, 4D modeling is often used to create a dynamic simulation of a building or infrastructure project over time. This includes the entire construction process, from the initial stages of planning and design to the completion of the project. [5]

The fourth dimension in 4D modeling represents the element of time, allowing stakeholders to visualize the project's progression through various stages. This integration of time provides a comprehensive understanding of how construction activities unfold over the course of the project's lifecycle. Construction scheduling software is often employed to link the 3D model with the project's schedule, enabling a synchronized visualization of the construction sequence.

In the higher education, 4D modeling can be used to create dynamic visualizations for engineering subjects, as well as natural science and humanities. Students can, for example, explore historical events, biological processes, or architectural developments over time, fostering a more interactive and engaging learning experience through the integration of the temporal dimension.

2. LITERATURE REVIEW

Many researchers have studied this problem in recent years. They researched the benefits and effectiveness of AR/VR in higher education.

Bermejo et al. [6] presented systematic literature review, focusing on learning immersion, which had positive effect on both learning and teaching process, especially in hospitality, medicine, and science studies. Their methodology was to review the experiences of teaching and learning using AR/VR in Higher Education Institutions by searching in selected scientific databases (Google Scholar, Science Direct, and IEEE Xplore), applying selection process to the obtained sample, and classifying the obtained information considering bibliometric indicators. They pointed out some negative effects of AR/VR application in education as well, such as visual exhaustion and mental fatigue.

Deepthi and Dr. Lakshmanan [7] studied the impact of augmented and virtual reality technology on modern society. AR and VR devices found its application in everyday life, not only by smartphone users, but also by both new and established businesses, and leading entrepreneurs. Because of that, it's expected that number of AR and VR devices will reach 105 million by year 2025. Their methodology is focused on AR/VR application through different platforms and game engines, such as Unity, Vulforia, etc. Authors suggest that there's space for future enhancements including user movement and interaction, menu and interfaces, different fields within education.

Osipova et al. [8] focused their study on use of new technologies in higher education in Ukraine. They did research about application of mobile and portable devices in the educational process, how software may help improve the quality of educational materials, and how educational purpose software may implement virtual and augmented reality into education. Virtual and augmented realities are unique learning environments in various fields of science, reproducing virtual models in details, which can help students better understand scientific problems. One of the problems students may face with is the fact that most software for learning in virtual and augmented reality have English language interface, so there's a need to develop educational software for Ukrainian speaking students.

Khanchandani et al. [9] performed a systematic analysis on how the role of AR on the learning process was measured and the viability of incorporating virtual reality in the learning environment.

VR offers new visualization approach to the presentation of learning about materials. This can help connect traditional schooling with the technology of the future. Their methodology focused on several things: various application domains of AR/VR, interest among students and teachers to use AR/VR, role of educators in the development process. Authors suggest that traditional format for teaching is no longer that useful, and that teaching the subject with the help of AR/VR will reduce its complexity and allow the students to better understand the concepts.

3. METHODOLOGY AND BENEFITS

This work aims to show the performance improvement AR/VR and 4D modeling can bring to higher education students. To achieve this aim, we performed a Literature Review. We were looking for some similar methodology, like the one proposed by [9]. Firstly, we collected data about students' performance before we started using AR/VR in that course (Spring 2023 semester). Secondly, we began using AR/VR technology and collected data again from the same course (Fall 2023 semester). Finally, we compared data and drew conclusion.

The integration of Augmented Reality (AR) and 4D modeling in higher education goes beyond theoretical instruction, offering students immersive experiences that bridge the gap between classroom learning and real-world application. Through these technologies, students can explore and apply concepts in a dynamic and interactive manner, preparing them for the complexities of their future professions. There are many benefits that significantly enhance the learning experience for students:

3.1. ENGAGING AND INTERACTIVE LEARNING

AR fosters interactive learning experiences by allowing students to actively engage with virtual content. This dynamic interaction, coupled with 4D modeling, transforms learning into a participatory and engaging process where students can manipulate time variables and actively participate in the exploration of dynamic processes.

3.2. REAL-WORLD APPLICATION AND SIMULATION

AR applications provide opportunities for real-world application by simulating scenarios relevant to various fields. For instance, architecture students can visualize building designs on physical sites, while 4D modeling extends simulation capabilities by allowing students to observe the evolution of processes over time, enhancing practical understanding.

3.3. PERSONALIZED LEARNING EXPERIENCES

AR applications can be personalized to cater to individual learning styles, allowing students to interact with content at their own pace. 4D modeling complements this by facilitating personalized learning journeys, where students can explore different stages of a process based on their understanding and preferences.

3.4. ENHANCED VISUALIZATION AND UNDERSTANDING

AR enables students to visualize complex concepts in three-dimensional space, making abstract ideas more tangible. 4D modeling, by incorporating time, adds a temporal dimension, allowing students to understand changes and developments over time, thereby deepening comprehension.

3.5. COLLABORATIVE LEARNING OPPORTUNITIES

AR supports collaborative learning by creating shared experiences. Students can work together in real-time, manipulating virtual elements collectively. 4D modeling enhances collaborative exploration, allowing students to collectively analyze and discuss changes over time, fostering teamwork and communication skills.

By incorporating AR and 4D modeling, educational institutions create an enriched learning environment that prepares students for the real-world challenges and opportunities.

4. APPLICATION

The integration of Augmented Reality and 4D modeling in higher education represents a paradigm shift in teaching and learning methodologies [10]. AR and 4D modeling can be employed in classrooms to provide interactive learning experiences.

In physics class, common problem is to comprehend complex concepts related to electromagnetic fields. Traditional methods involve static diagrams and equations on the whiteboard. However, Augmented Reality (AR) transforms this challenge into an immersive learning experience. Equipped with AR devices, students engage with virtual 3D models that demonstrate the dynamic nature of electromagnetic forces. They can witness magnetic field lines in real-time, manipulate charged particles, and observe the effects of electromagnetic induction, turning abstract theories into a visual and interactive exploration.

In a chemistry lab, students are learning about molecular structures. With AR, traditional molecular model kits are replaced by virtual 3D representations. Students can manipulate and rotate these molecular structures, gaining a deeper understanding of chemical compounds and their interactions.

In an urban planning class, a different problem emerges: understanding the transformation of cityscapes through various developmental phases. 4D modeling becomes a powerful tool. Students utilize 4D simulations to observe how urban spaces evolve over time. They can analyze the impact of different planning decisions, such as zoning changes or infrastructure developments, on the overall city layout. This immersive approach not only deepens their understanding of urban dynamics but also equips them with practical skills for effective urban planning.

Here in American College of The Middle East (ACM), we've recently obtained Meta Quest 3 AR/VR set (Figure 1 and Figure 2).

Figure 1. AR/VR set.

Figure 2. AR/VR headset.

In one of the Civil Engineering courses (Architectural Engineering Construction), we use this set to let students better understand their Revit model design. That is a crucial part of a Course project, since students have to evaluate their design before submission. After completing their design in Autodesk Revit (Figure 3), students upload the design into an AR/VR set (Figure 4).

AR/VR set proved beneficial, because it provides much better insight into the design, identification of design flaws and therefore simplifies design improvement process. Not only that application of AR/VR set helped students better understand complex engineering problems, but it also helped them perform better and achieve higher grades in the same Project deliverable compared to previous semester which was conducted using PCs only (Table 1).

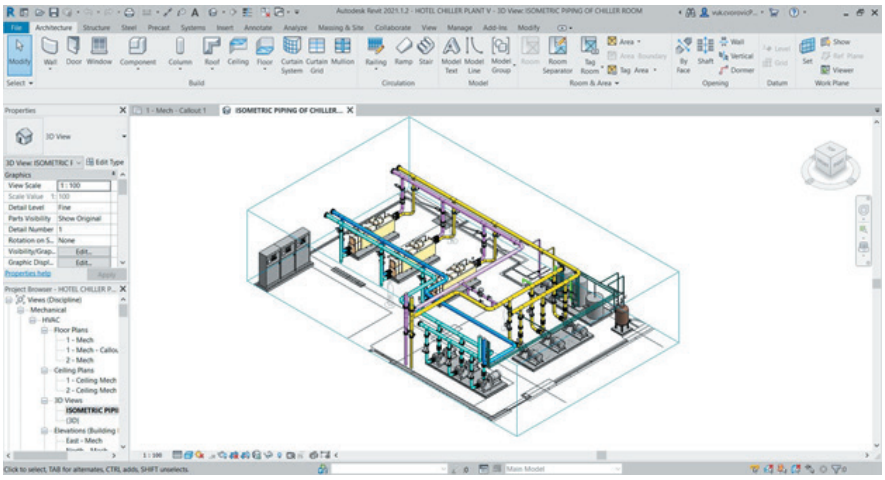

Figure 3. AR/VR set.

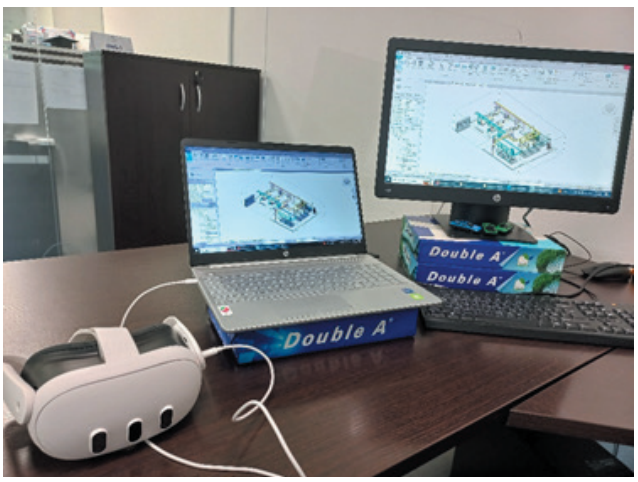

Figure 4. AR/VR headset.

Table 1. Result comparison (Spring/Fall 2023) for Project deliverable 3.

Semester	Assignment	Equipment	Software	Number of students	Average grade
Spring 2023	Project deliverable 3 (Design evaluation)	PC	Autodesk Revit	29	72.34/100
Fall 2023	Project deliverable 3 (Design evaluation)	PC, Meta Quest 3	Autodesk Revit, Oculus	27	

Because of the above-mentioned results, we plan to expand utilization of this AR/VR set to other engineering programs in upcoming semester.

5. CHALLENGES AND CONSIDERATIONS

The adoption of Augmented Reality (AR) and 4D modeling in higher education promises transformative learning experiences, but it also brings forth a set of challenges and considerations that educational institutions must navigate. Addressing these issues is crucial to ensuring successful implementation and maximizing the benefits of these innovative technologies.

One of the primary challenges lies in the potential cost implications associated with implementing AR and 4D modeling. Institutions may face the problem of allocating substantial budgets for the acquisition of AR devices, development of content, and maintenance of technical infrastructure. This financial hurdle can be a significant barrier to entry, particularly for institutions with limited resources. To mitigate this, a strategic financial plan is essential, and institutions may need to explore collaboration with external partners or seek additional funding sources. Fine example of dealing with this potential problem is provided in [11]. Mohammadi and Martins [11] proposed a model for conducting a cost-benefit analysis for implementing virtual reality in construction companies. First, they identified the cost and benefit factors through a literature review and considered input variables for the model. Then, using synthetic data, a distribution of outcome was generated by performing Monte Carlo simulation. From the results, they concluded that in 5 years, the implementation of VR could show positive results in construction companies and be a reasonable investment.

Device accessibility poses another technical challenge. The problem arises from economic disparities among students, leading to unequal access to AR devices. This can result in a digital divide, where certain students are unable to fully participate in AR-enhanced learning experiences. To address this challenge, institutions need to consider a range of solutions. Providing AR devices, adopting a bring-your-own-device (BYOD) approach, or offering alternative means of accessing content for students without AR devices are potential strategies.

Effective integration of AR and 4D modeling into existing curricula is a pedagogical challenge. Faculty may face resistance or lack the necessary training to seamlessly incorporate these technologies into their teaching methodologies.

This poses a problem as the success of AR implementation hinges on its alignment with educational goals. To overcome this, institutions need to invest in faculty development programs, workshops, and incentives that encourage educators to explore and integrate AR and 4D modeling into their teaching practices. Collaborating with instructional designers and providing ongoing support is vital to align technology use with learning objectives.

Equity in access is a significant consideration for ensuring inclusivity. The problem arises from economic disparities that may result in unequal access to AR devices and technology. This challenge can lead to a scenario where certain students are left behind due to a lack of access. Institutions must implement strategies such as device lending programs, subsidies, or ensuring access to AR-equipped facilities on campus. Additionally, promoting open-access resources and reducing reliance on expensive devices can enhance inclusivity. Good example of how this can be overcome is provided in [12]. Isa [12] shows that National Library Board (NLB), Singapore, has developed four immersive storytelling (IST) rooms in various libraries throughout the country. In one of them (Bukit Panjang Public Library), after the implementation of the immersive room, the storytelling attendance increased to 700% in the first 6 months. The exhibitions and other services that library provides also recorded increase in user access, all because of application of AR and VR technology.

Digital distraction and ethical use pose ethical challenges. The problem arises when AR applications contribute to digital distraction or are misused, leading to disengagement from the learning process. Institutions need to establish guidelines for the ethical use of AR and promote responsible technology usage. Educators should design AR experiences thoughtfully, ensuring they align with educational goals and minimize distractions. In ACM, we promote ethical and responsible use of AR through Ethics Campaign conducted on weekly basis throughout the entire semester. Instructors teach students how to act responsibly by presenting PowerPoint slides, YouTube videos and other content about Academic Integrity and Ethics.

6. CONCLUSION

AR and 4D modeling already found application in higher education. In this research, authors explored benefits that this application may bring to students. Provided example illustrates that very well. The potential benefits of integration of AR and 4D modeling in higher education include enhanced engagement, real-world application of concepts, and personalized learning experiences, which makes these technologies valuable assets in the educational landscape. However, challenges such as technical infrastructure requirements, cost implications, and ethical considerations must be addressed for widespread adoption.

There are some areas of AR and 4D modelling application in higher education that can be explored furthermore, especially the ethical aspect. Further research is needed to determine how content can be customized for individual students (e.g. special needs students), how to control the content presented to students and at the same time give student liberty in using the equipment. These topics can be starting point for another research about application of AR and 4D in higher education.

As technology continues to evolve, the relationship between AR, 4D modeling, and higher education will help in developing a more dynamic and immersive learning environment for both students and educators. Therefore, an initiative from educators' side to explore the potential of AR and 4D modelling in their environment can be very beneficial and speed-up the process of implementation of this technology in higher education. That may offer higher education students a dynamic perspective, enrich understanding, foster engagement and prepares students for the challenges of their academic pursuits.

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