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A STUDY ON THE EFFECT OF XR TECHNOLOGY APPLICATION EFFICIENCY AND AUDIENCE IMMERSION IN VIRTUAL STAGES OF WEB SKITS TO BETTER UNDERSTAND STUDENTS

UM ESTUDO SOBRE O EFEITO DA EFICIÊNCIA DA APLICAÇÃO DA TECNOLOGIA XR E DA IMERSÃO DO PÚBLICO EM PALCOS VIRTUAIS DE SKETCHES ON-LINE PARA MELHOR COMPREENSÃO DOS ALUNOS

UN ESTUDIO SOBRE EL EFECTO DE LA EFICIENCIA EN LA APLICACIÓN DE LA TECNOLOGÍA XR Y DE LA INMERSIÓN DEL PÚBLICO EN ESCENARIOS VIRTUALES DE SKETCHES EN LÍNEA PARA UNA MEJOR COMPRENSIÓN DE LOS ESTUDIANTES

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ABSTRACT: This article examines the use of Extended Reality (XR) technologies to enhance learning through interactive simulations, reenactments, and scientific visualizations. It presents a structured framework for understanding how XR is applied in cultural heritage education to improve motivation, comprehension, and user experience. The study focuses on how technical students understand XR 3D visualization and proposes a unified training approach to strengthen both theoretical and practical skills. It also evaluates how this instruction shapes students' perceptions of XR across different contexts. Results show significant improvement in participants' technical abilities and more positive attitudes toward XR after completing the course. The findings suggest that targeted XR training better prepares students for the technological demands of their fields. The paper also offers insights for optimizing XR use in architectural design education and provides strategic recommendations for curriculum development and technological innovation to support evolving professional practices.

KEYWORDS: Extended reality (XR). Virtual reality (VR). Cultural heritage. Practical skills. Students.

RESUMO: *Este artigo examina o uso de tecnologias de Realidade Estendida (XR) para aprimorar o aprendizado por meio de simulações interativas, reconstituições e visualizações científicas. Apresenta uma estrutura organizada para compreender como a XR é aplicada no ensino de patrimônio cultural para melhorar a motivação, a compreensão e a experiência do usuário. O estudo concentra-se em como estudantes de cursos técnicos compreendem a visualização 3D em XR e propõe uma abordagem de treinamento unificada para fortalecer tanto as habilidades teóricas quanto as práticas. Também avalia como essa instrução molda a percepção dos alunos sobre a XR em diferentes contextos. Os resultados mostram uma melhora significativa nas habilidades técnicas dos participantes e atitudes mais positivas em relação à XR após a conclusão do curso. As descobertas sugerem que o treinamento direcionado em XR prepara melhor os alunos para as demandas tecnológicas de suas áreas. O artigo também oferece insights para otimizar o uso da XR no ensino de projeto arquitetônico e fornece recomendações estratégicas para o desenvolvimento curricular e a inovação tecnológica, visando apoiar a evolução das práticas profissionais.*

PALAVRAS-CHAVE: *: Realidade estendida (XR). Realidade virtual (VR). Patrimônio cultural. Habilidades práticas. Estudantes.*

RESUMEN: *Este artículo analiza el uso de tecnologías de Realidad Extendida (XR) para mejorar el aprendizaje mediante simulaciones interactivas, reconstrucciones y visualizaciones científicas. Presenta un marco organizado para comprender cómo se aplica la XR en la enseñanza del patrimonio cultural con el fin de mejorar la motivación, la comprensión y la experiencia del usuario. El estudio se centra en cómo los estudiantes de cursos técnicos comprenden la visualización 3D en XR y propone un enfoque de formación unificado para fortalecer tanto las habilidades teóricas como las prácticas. También evalúa cómo esta instrucción influye en la percepción que los estudiantes tienen de la XR en distintos contextos. Los resultados muestran una mejora significativa en las habilidades técnicas de los participantes y actitudes más positivas hacia la XR tras la finalización del curso. Los hallazgos sugieren que la formación especializada en XR prepara mejor a los estudiantes para las demandas tecnológicas de sus áreas. El artículo también ofrece aportes para optimizar el uso de la XR en la enseñanza del diseño arquitectónico y presenta recomendaciones estratégicas para el desarrollo curricular y la innovación tecnológica, con el objetivo de apoyar la evolución de las prácticas profesionales.*

PALABRAS CLAVE: *Realidad Extendida (XR). Realidad Virtual (VR). Patrimonio cultural. Habilidades prácticas. Estudiantes.*

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INTRODUCTION

Critical competences for both technical and non-technical students are the fundamentals of science and information technology. The ability or knowledge needed to carry out practical activities in the fields of science, the arts, technology, engineering, and math is known as scientific talents (Abhari et al., 2021). The capacity to find, gather, and process data as well as apply it critically and methodically are all part of IT abilities. Contemporary immersive technologies like virtual reality (VR), mixed reality (MR), augmented reality (AR), and (Kharvari et al., 2022) provide fresh insights into the architecture of educational settings. XR systems were categorized by Milgram et al. (1994) using a "virtuality" continuum that connects the real and virtual worlds.

In education, where virtual enrichment can be mixed with real-world experiences, their method highlights the significance of combining virtual and physical elements. According to pedagogical theories, XR technology can be included into a constructivist educational framework. Students build knowledge through social interaction and reflection on their experiences, according to social constructivism, a popular theory of learning (Wang et al., 2022). XR technology integration makes it possible to create genuine learning settings that mimic real-world professional situations, which aligns with authentic learning models and problem-based learning (Milgram et al., 1994).

The VR, AR, and MR technology have transformed a number of industries in recent years, from architecture and engineering to healthcare and education. Using the reality–virtuality continuum spectrum, this work employs expanded reality (XR) to comprehensively classify these digitally created real and virtual settings (Thomas, 2005) Figure 1. Because architecture design relies on visualizing and manipulating spatial things, XR's capacity to create an immersive and interactive 3D environment puts the architectural sector at the forefront of XR applications (Shin et al., 2005).

The first is a camera work training virtual rehearsal system (1), which is more akin to virtual reality than mixed reality. It allows users to evaluate camera functionality in fully virtual surroundings that are created using computer graphics and mimic actual camera motion. Using a tiny monitor that is fixed to the camera body, the user can view the current camera angle. A marker-based infrared tracking system measures the camera's movements. The expense of actors and stage décor can be decreased with this method.

The second is a pre-visualization technique that makes use of augmented virtuality. It is made to function in an actual studio (Figure 1 [2]). utilizing a chroma key technique in a scene that has already been visualized. A unique retro-reflective material is used to extend the chroma key method and give the director and actors a variety of perspectives. We can lower stage decoration costs by using this technique. Finally, augmented reality is used for

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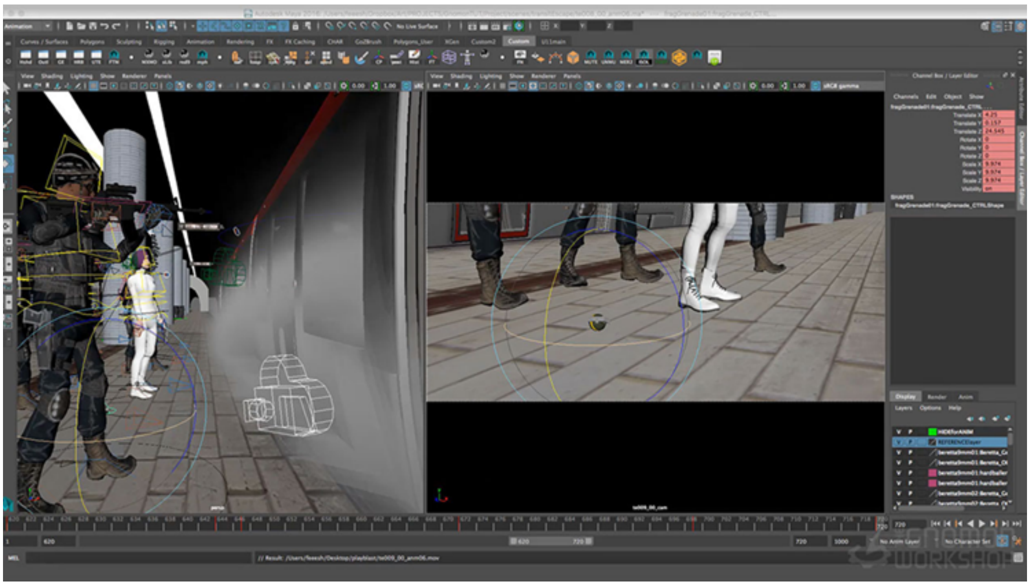
pre-visualization (Ikeda et al., 2008). For scene composition and camera pose/motion control in the real world, AR storyboard (4) offers an easy-to-use interface.

This method lowers the expense of performers performing in the actual scene. Every pre-visualization method mentioned above is intended for indoor settings. Accurate camera posing in outside settings is challenging in the absence of sensors and markers. The final type of real-time previsualization methods, require estimating the precise 6 DOF camera pose in order to register virtual actors or objects in every actual video frame. For real-time outdoor pre--visualizations, there aren't any real-time estimating techniques that work well. As illustrated in Figure 1, in this study we offer a real-time pre-visualization strategy for outdoor situations that include complex scenarios like natural items.

Figure 1

A pre-visualized scene (7, 8)



Note. Elaborated by authors (2025).

The VR has been proposed as a potential means of boosting student engagement since it allows students to create customized avatars that reflect who they are. A more immersive and appealing learning experience may be obtained by merging these avatars with facial expression and emotion detection technology to build interactive settings that mirror real-world features (Diao & Shih, 2019; Safikhani et al., 2022). Even though some students have demonstrated potential in lowering disengagement, this approach is not a panacea, and each student's preferences and the specific learning environment can affect how effective it is (Ikeda et al., 2008). Virtual reality learning is at the forefront of scientific education because it allows students to visualize concepts in a realistic way (Lin et al., 2023). Students can learn more efficiently and concentrate because immersive activities in a VR headset totally capture their vision and attention, reducing the opportunity for distractions or multitasking.

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The VR can greatly improve education by providing captivating, interactive simulations that increase student engagement and retention by making experiences that were previously unavailable in the classroom—like historical settings or intricate scientific structures—more accessible. In contrast to conventional teaching techniques, Stanford University's studies, for example, showed that VR can greatly increase student engagement and retention rates (Najereh et al., 2017). Furthermore, (Tsai et al., 2024), VR has the potential to democratize education by offering easily accessible, immersive virtual field trips and cultural exchanges, assisting students in overcoming financial or geographic obstacles.

Through the practice of tasks like engineering feats or medical procedures in a risk-free setting, VR also helps students enhance their skills and engage in experiential learning. Medical students' anxiety levels were found to decrease while their real-life surgical performance improved thanks to virtual reality simulations, according to Stanford University's Medicine program. A recent study showed that by bringing students together across distances and encouraging group interactions, VR improves collaborative and social learning.

Additionally, the study discovered that VR-based teamwork greatly enhances communication abilities and general learning results. In conclusion, VR is a useful instrument for professional development and teacher training, giving teachers the tools they need to successfully incorporate this technology into their lesson plans.

The AR, which moves away from the immersive realms of VR, seamlessly combines digital information with our physical environment. Augmented Reality overlays digital features on top of our physical world rather than creating a completely virtual environment. With the growth of smartphone applications in the late 2000s and early 2010s, this blending of worlds attracted a lot of attention.

VR and AR are combined to create mixed reality (MR), which creates new landscapes where digital and physical items coexist and interact in real time. The introduction of gadgets like the Microsoft HoloLens, which made it possible to incorporate holographic digital content into the real world, allowed for a more thorough development of this idea.

The term "extended reality" (XR) refers to a broad category of immersive technologies and the experiences they produce. It blends the spectrum of virtual and physical worlds. XR encompasses technologies such as VR, AR, and MR. At the nexus of multiple technical advancements, XR offers a plethora of opportunities across industries. XR has the potential to transform businesses, alter human-computer interactions, and create immersive experiences that were previously only found in science fiction by linking the real and digital worlds. From AR-enabled retail experiences that let customers sample things in real time, which lowers return rates and increases happiness, to virtual patient simulations that enhance abilities, XR is increasing engagement across industries like healthcare, retail, and training.

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As technology develops, it may become harder to distinguish between VR, AR, and MR, which could result in more seamless and integrated experiences (Safikhani et al., 2022). Additional developments in AI and 5G, which improve XR's responsiveness and accessibility, are projected to make these tools indispensable in everyday life; wearables and XR headsets are already becoming more widely used.

Audio-visual, real-time perception, and music visualization

Visual imagery plays a significant influence in eliciting emotions and improving the listening experience of music, according to research. Its exact nature, intent, and frequency are yet unknown, though. Music visualization improves audience immersion and helps them better understand performances, according to earlier research (Safikhani et al., 2022). Audiences are captivated by the way music and visuals interact, and a successful live performance depends critically on striking the correct audio-visual balance Safikhani et al., 2022). Visual Jockeys (VJs), who use the beats, timing, and structure of the music to create visuals, frequently get pre-recorded audio files from performers. Audio and visuals are separated in this way, and most performances are prearranged with no real-time contact.

Virtual Co-presence and XR Concert

Enhancing crowd participation and involvement to boost immersion in virtual reality performances has been the topic of prior research. Users can enjoy live recordings, for instance, from a free viewpoint with adjustable sound control, collecting real-time signals and turning them into a virtual scene to create an immersive experience (Safikhani et al., 2022). A real-time emotional visualization system that enhances the emotional bond between live and virtual audiences by synchronizing the performer's movements, audience interactions, and music.

Many performances use XR technology with live performances in addition to completely virtual concerts. An online concert platform called Beyond LIVE was developed in Asia by SM Entertainment in South Korea. It combines real-time 3D images, augmented reality technology, and artist performances to produce a visually stunning experience. Attendees of the band Miro Shot's 2019 (Safikhani et al., 2022) XR concert put on virtual reality headsets and entered a multisensory immersive setting featuring fans, dry ice, and fragrances. Immersion virtual musical instrument (IVMI) performances on stage present both conceptual and technical difficulties, and suggestions for design and implementation of immersive performances in the future have been made (Shirzadian et al., 2017). Performers and spectators can now engage musically with virtual objects, agents, and surroundings thanks to the substantial growth of the music-XR nexus.

XR Performance Design Considerations

Field deployment subtleties are crucial in the fast-paced realm of live performances. Traditional methods provide useful design insights, from comprehending stakeholder needs to resolving issues brought on by various locations and audience configurations. Grounding our strategy in these fundamental behaviours is crucial as we transition to hybrid models. To lay a solid basis for developing hybrid performance models, we thus start by investigating the design issues of onsite performances (Turchet et al., 2021). We planned four events to gain a better understanding of the difficulties involved in presenting live performances: a technical display with 60 guests, a music concert with 2,000 attendees, and two opening ceremonies with roughly 100 and 300 attendees. We solicited input from band guitarists who were invited to use our XR performance system during these events.

Because AR allows users to observe real-world sites and objects, it improves their interaction with cultural heritage-related educational materials. Through the digital overlaying of information, AR produces a contextualized visualization that improves comprehension. However, VR makes it possible to fully recreate cultural heritage places and buildings in a fully immersive 3D environment, giving users the opportunity to remotely examine artifacts and historical locations for a more engaging and educational experience (Yakura & Goto, 2020). Through MR's integration of the physical and virtual worlds, users can interact or engage with historically significant things and locations while they are physically present, providing chances for experiential learning.

The term user experience (UX) describes the study, planning, and assessment of how users behave when interacting with systems, services, or goods. UX is defined as a person's reactions and impressions of a system, product, or service by ISO 9241-210. Because immersive experiences are so special, the concept of UX has been frequently used to the analysis of visitor experiences at museum and virtual historical locations (Santini, 2024). UX is impacted by a user's psychological state (behaviour, expectations, requirements, and motivation), the system or product's features (complexity, purpose, usability, and function), and the context (e.g., social and organizational environment, meaningful activity, and voluntariness of use).

The purpose of this research is to examine how 3D XR visualization affects students' technical competency development in engineering education. Our hypothesis is that focused instruction utilizing XR technology will enhance students' technical proficiency and impact their perceptions of these resources. The project will evaluate students' creation of 3D content for AR, MR, (Easdon, 2020), and VR visualizations as well as their understanding of XR technology.

Additionally, we believe that rigorous XR training will improve students' practical capabilities in technical domains, better equipping them for the modern workforce where high-tech abilities are becoming increasingly crucial.

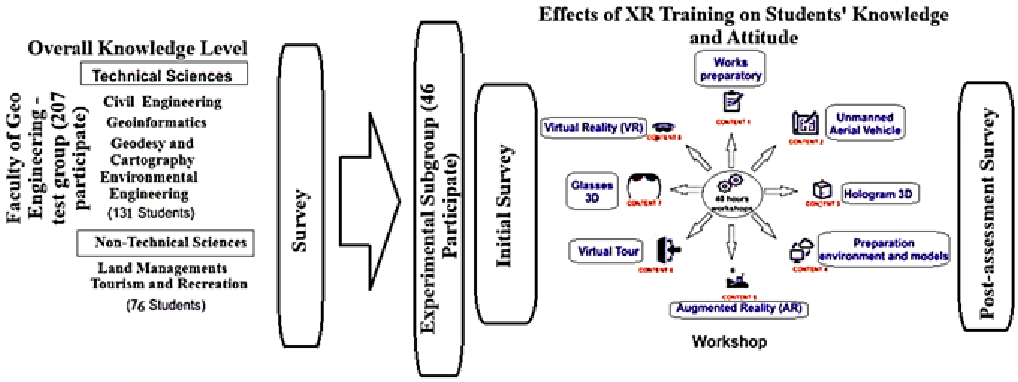
Key research questions have been developed in order to answer these presumptions: When learning with XR technology, what challenges do students encounter? What is the impact of using XR in technical education on students' technical skill development? Does XR instruction have a good impact on students' (Yakura & Goto, 2020) perceptions of these technologies and how they will be used in the workplace going forward? By answering these questions, we may better comprehend the possible influence of XR technologies on the development of contemporary technical competencies and provide a detailed methodological framework for the study.

METHOD

The first phase of the study involved surveying 207 students from the multidisciplinary geoinformatics faculty who were enrolled in a variety of technical and social scientific courses, including environmental engineering (131 people in the technical sciences), land administration, tourism, and recreation (76 individuals in the non-technical science fields), civil engineering (Yan et al. 2020; Zappi et al., 2022), geoinformatics, geodesy, and cartography, and more. The survey was conducted online in an anonymous manner and had seven closed-ended questions. The questions centered on the students' familiarity with AR, VR, MR, holograms, simulated tours, and unmanned aerial vehicles (Scippo et al., 2024). A subjective evaluation of the degree of difficulty in utilizing and setting up a workspace with these gadgets was also requested in the questionnaire. The survey also inquired as to whether these advances in technology were covered in the classes and whether the curriculum should incorporate them.

Figure 2

Framework for conceptualizing how to evaluate students' general knowledge and how XR instruction affects their attitudes and knowledge levels



Note. Drugova et al. (2021).

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Description of the workshop

Participants from multidisciplinary geoinformatics faculty participated in the workshop, which took place between December and March 2023 (Cai & Zhang, 2024). Utilizing visualization technology based on eXtended Reality was the focus of the session (Arnab et al., 2024). Figure 2 shows a schematic of the workshop program.

Each topic block is briefly described in the next paragraph, which also describes the resources utilized in the teaching process (Arnab et al., 2024).

Augmented reality (AR)

Participants in the AR course learned about this kind of technology and how to use the Vuforia Library and the Unity 3D development environment to construct mobile applications (Chen & Konomi, 2024). The lesson also covered various approaches to displaying and positioning 3D objects in space, such as location-based on image identification (marker), position-based utilizing GNSS, and location-based after recognizing feature points and plane. Additionally, mixed approaches (Suryodiningrat et al., 2024), which incorporate multiple location methods, were examined.

Virtual reality (VR)

The hardware specifications for VR were presented at the workshop. In addition to the development of Virtual Tour or Unity-based solutions, the VR displays was tested with cell phones and VR adapters (Janssen et al., 2016). The setup and upkeep of VR environments using gadgets like the Oculus Rift and HTC VR VIVE Pro Eye, where content creation is carried out with a PC, were described (Gonizzi Barsanti et al., 2015). Students were taught how to distinguish between the settings on standalone HTC VIVE Pro Eye and Oculus Quest 2 devices.

Hologram

In the course of the session, students were exposed to a variety of technologies that show three-dimensional visuals (Hammady et al., 2020). They were initially introduced to anaglyph spectacles, which block out red and blue using filters in one lens and the other lens, respectively. Together, the two images are processed by the brain to produce a three-dimensional environment (Han et al., 2019). Using distinct visuals for each eye in 3D movies was another topic discussed in the session.

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Virtual Tour

A virtual tour is an engaging method of discovering and studying locations, artifacts, or structures. Users can view a three-dimensional environment on a computer or cell phone by using a web browser Virtual Tour (Dunleavy & Dede, 2024). This technology, which enables tourists to view a graphical representation of a place from the comfort of their homes, is used extensively in the retail, real estate, and tourism sectors. Virtual tours can be accessed on a computer, tablet, or smartphone and are based on AR and VR.

Unmanned aerial vehicle (UAV)

Participants in the UAV-related classes learned about Poland's drone usage regulations and permits. Information and a summary of the required authorizations were supplied by the Civil Aviation Authority. Participants tested their abilities using flight simulators during the class's practical portion. They may alter the weather and select the kind of drone to practice fundamental UAV handling and manoeuvres.

3D modelling

In the 3D modeling portion of the class, participants learned how to use a variety of software programs, both free and commercial, to produce a 3D model of an object (Dunleavy & Dede, 2014). Among the software applications that were introduced was Agisoft Metashape, which made it possible to create 3D models from photography.

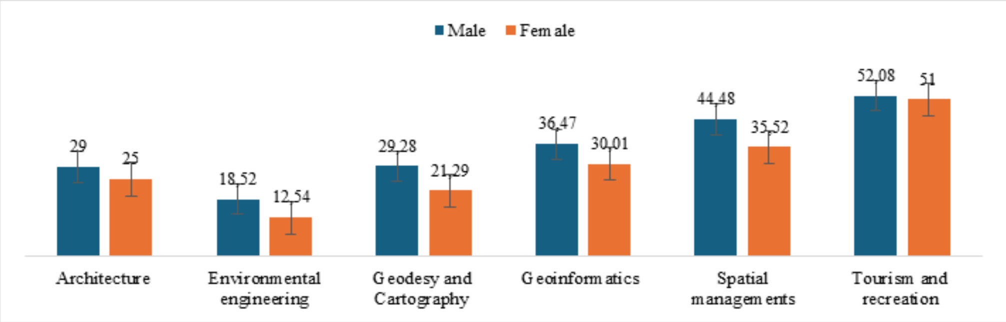
To create the final 3D model, the procedure comprised organizing the data gathering, taking pictures or using a mobile device to scan the object, and then entering the data into the software (Essoe et al., 2022). Additionally, the participants were taught about the different options that impact the quality of the model, including the texture and colour settings, as well as the quantity of points generated. After that, they may use the 3D model in virtual worlds like gaming or virtual tours of buildings and museums.

Students' baseline understanding

In the multidisciplinary geoinformatics faculty, 207 students completed an initial survey (Figure 3) (Evangelidis et al., 2020).

Figure 3

The attributes of the person's gender and assessed field

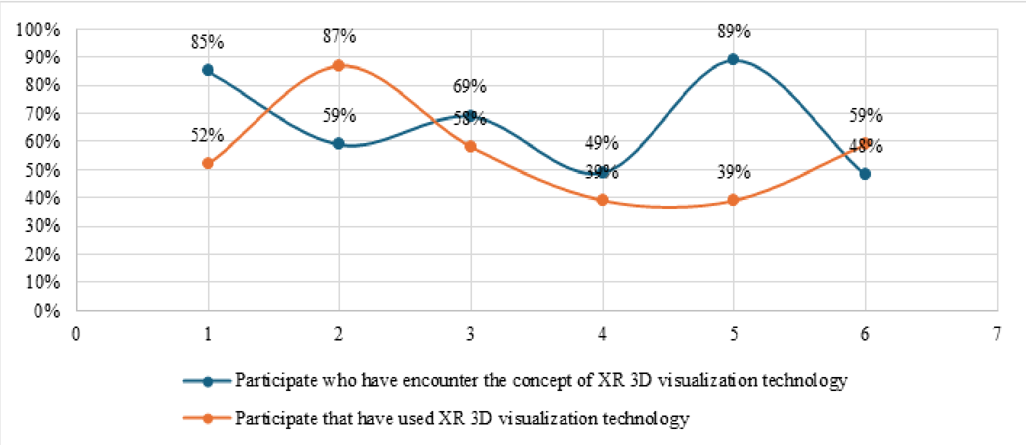


Note. Elaborated by authors (2025).

Students' familiarity with the technologies they studied and their capacity to differentiate between them differed. Survey respondents' combined answers are shown in Figure 4 (Essoe et al., 2022).

Figure 4

Respondents' technological understanding of the 3D depiction of eXtended Reality

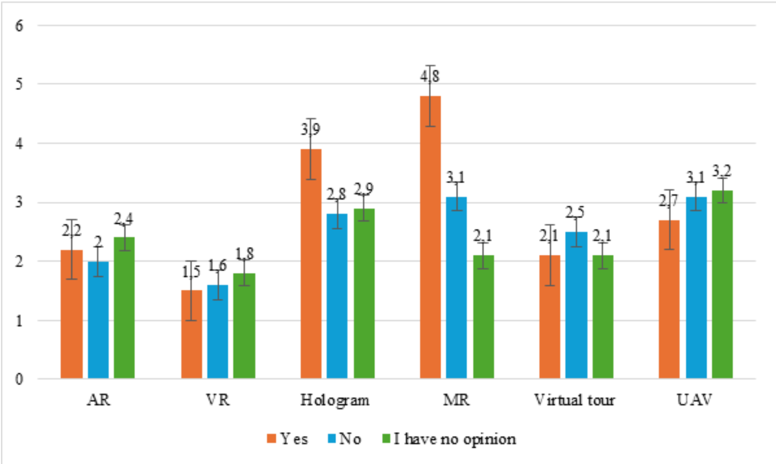


Note. Elaborated by authors (2025).

Using 3D visualization technology was another question in the poll. Only a small percentage of respondents employed these technologies, as seen by the direct result of the previous question. However, respondents (65% and 63%) say that using technology like virtual reality and virtual tours is really simple Figure 5.

Figure 5

The degree to which eXtended reality visualization technology is challenging to use



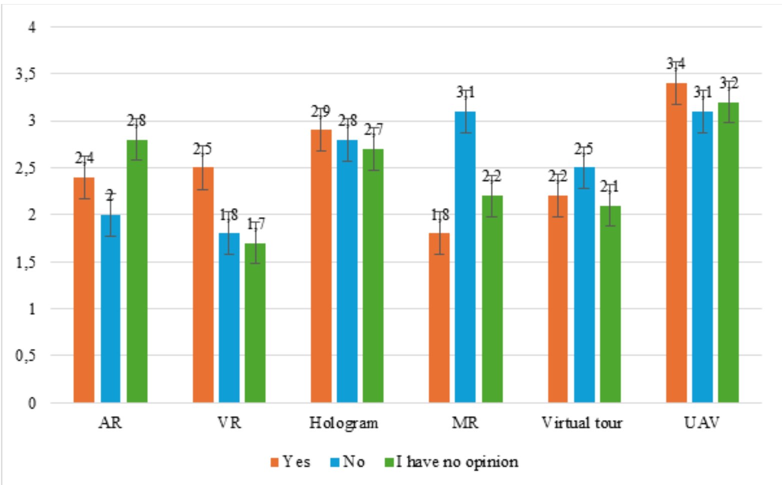
Note. Chiao et al. (2018).

It seems that many students are unsure about how to use and build solutions with these technologies because of their complexity (Baca et al., 2021, Fombuena, 2017). Since many of them think that creating their solutions with modern technologies is difficult, education and training in this field can be quite helpful.

Regarding the difficulty of developing their own solutions using the aforementioned technologies, most respondents selected "I have no opinion" (range from 38% of respondents for VR to 57% of respondents for MR), while only a small percentage of respondents used 3D visualization tools Figure 6 (Fombuena, 2017, Kotarski et al., 2021).

Figure 6

The degree of complexity involved in setting up a workspace using eXtended Reality 3D visualization tools



Note. Mutis e Antonenko (2022).

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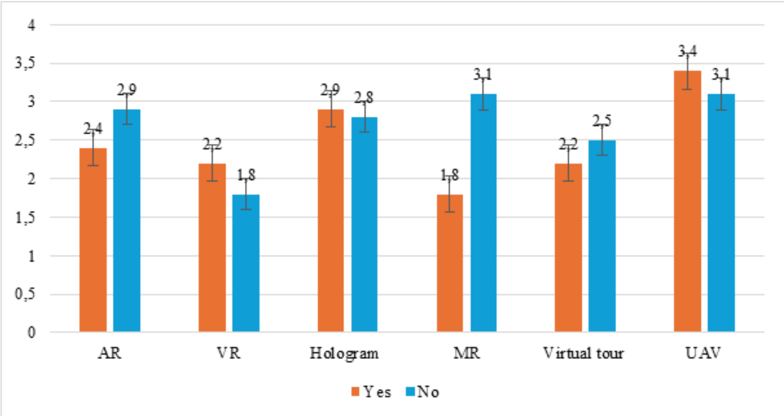
Respondents were questioned in the survey if they thought various technologies should be taught in their areas of study and whether they were covered in their classrooms (Figure 7 (Liono et al., 2021). The vast majority of participants said that they learnt about these technologies elsewhere and that they were not often covered in their lectures.

Figure 7

Current state of Extended Reality 3D visualization technology use in education

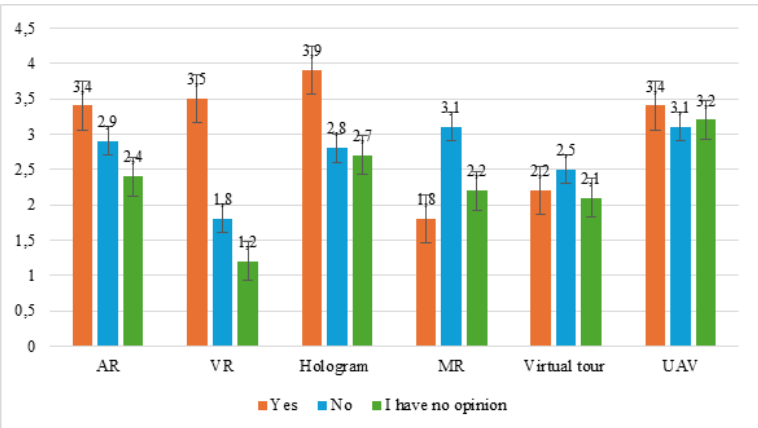


Note. Elmqaddem (2019).

Even though these technologies were seldom discussed in the classroom, suggesting a lack of understanding and experience, many people thought they need to be included in their course of study (Martín-Gutiérrez et al., 2017). Holograms (55%), virtual tours (59%), and virtual reality (62%), were among the most popular options. An overview of the replies about whether or not these technologies should be taught in classrooms is shown in Figure 8.

Figure 8

Extended Reality 3D visualization technology is required to provide didactic courses



Note. Ogunseiju et al. (2022).

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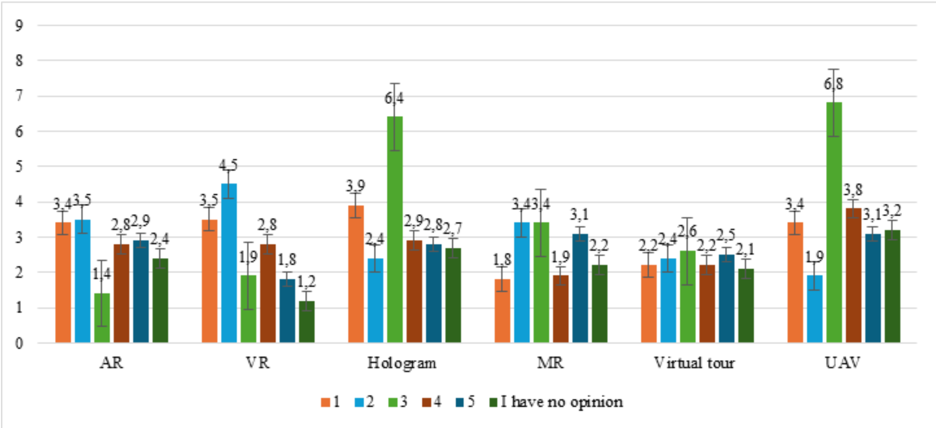
Students were asked to rate how applicable the technologies under analysis will be to their future job in the last question (Martín-Gutiérrez et al., 2017). Many students choose to select the "I have no opinion" response because of the lack of understanding and class debate. However, the greatest percentage of "5" ratings (extremely helpful) were given to virtual tours (27% of respondents) and virtual reality (20% of responses), suggesting that these technologies are highly valued Figure 9.

Figure 9

Extended Reality 3D visualization technology's applicability for upcoming projects



Note. Ogunseiju et al. (2022).

EVALUATION DIAGNOSIS

In order to expand knowledge and gauge changes in attitudes, we held training workshops as part of the subsequent stage of our study on eXtended Reality 3D visualization. 20 males (43%) and 27 women (57%) made up the 47 participants that filled out the questionnaire. Three of the participants were studying tourism and recreation, two were researching civil engineering, nine were studying geodesy and cartography, and thirty-three were studying land management. Our findings are shown below after we examined the answers to questions that were comparable to those in the original survey. Considering that it was carried out after the session, the analysis was evaluative.

Do you find using the technology you've studied difficult?

Upon examining the survey findings, it is evident that respondents' perceptions of the degree of difficulty in using different technologies vary significantly (Figure 10):

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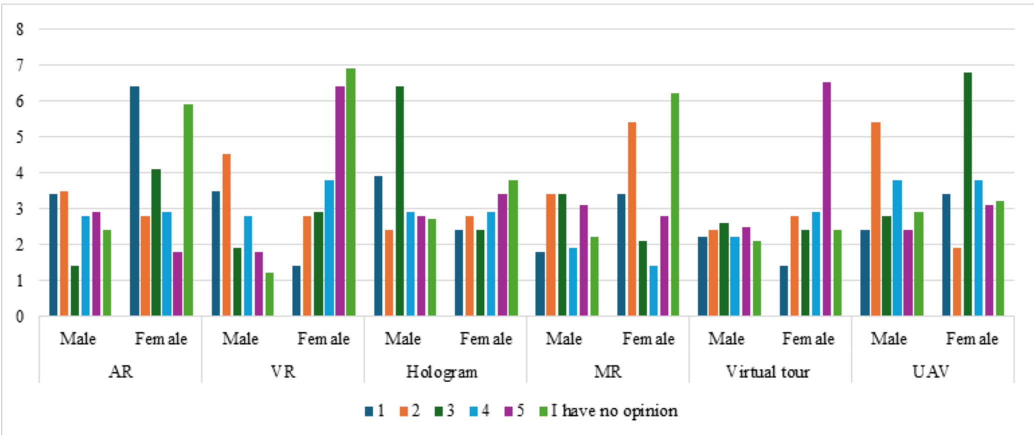
- The majority of evaluations for AR were 1 or 2, indicating that people find it simple to use or moderately difficult. This made AR the most accessible technology;
- Additionally, respondents regarded VR as rather straightforward to use, with some giving it better scores than AR, suggesting some degree of hesitancy;
- Due to the equal distribution of votes, MR garnered a range of viewpoints. While some respondents thought it was simple to use, others said it was more complicated;
- With ratings ranging from 1 to 5, holograms were classified as moderately complicated to tough, suggesting possible technical difficulties or a need for further technological knowledge;
- Virtual tours were rated well by most respondents, who said they were either simple to use or fairly difficult;
- Of all the technologies covered, using drones or UAVs was ranked as the most challenging; several of the scores were three or higher, suggesting a greater degree of complexity;
- With average scores below 2.5, all technologies were thought to be quite straightforward to use, with the exception of UAVs (2.56). This implies that the potential of the technology is shown by its present state of development. Nevertheless, the intricacy might impede its growth, necessitating the proficiency to implement XR-based remedies.

Figure 10

The degree of complexity of utilizing the 3D visualization technology of eXtended Reality (1-very easy, 5-very tough)



Note. Elaborated by authors (2025).

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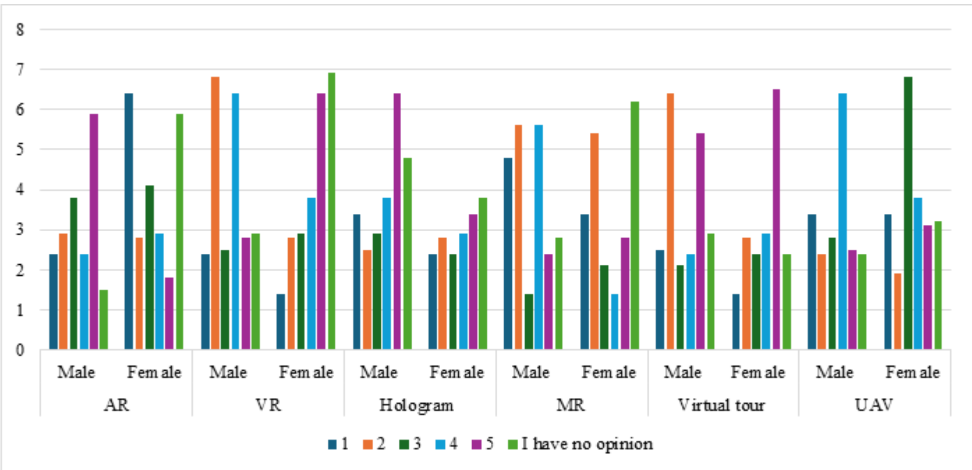
Do you find it difficult to use the tools you've learnt to develop a work environment?

We noticed the following after examining the survey data about the challenges of setting up a digital workspace (Figure 11):

- With scores mostly ranging from 2 to 3, the majority of respondents assessed developing a work environment in AR as somewhat difficult;
- The majority of scores fell between 1 and 3, indicating that creating a work environment in virtual reality was simple to moderately complicated;
- MR and VR were rated similarly, suggesting that integrating this technology into a work setting is thought to be fairly challenging;
- Although the scores for holograms were more varied, many of them were 2 or 3, indicating a moderate level of difficulty;
- With the majority of scores at 1 or 2, virtual tours are the easiest technology to incorporate into a workplace;
- Similar to holograms, UAVs were given a wide range of ratings, with the majority falling between two and three, which indicates intermediate difficulty;
- It is considered significantly more difficult to create a workable environment utilizing previously taught technologies than to utilize them, especially for AR (2.68), MR (2.72), and holograms (2.22). This implies that while these technologies are simple to use on their own, integrating them into a work setting might be difficult.

Figure 11
Complexity level of setting up a workspace using eXtended reality 3D visualization tools (1-very simple, 5-very tough)



Note. Elaborated by authors (2025).

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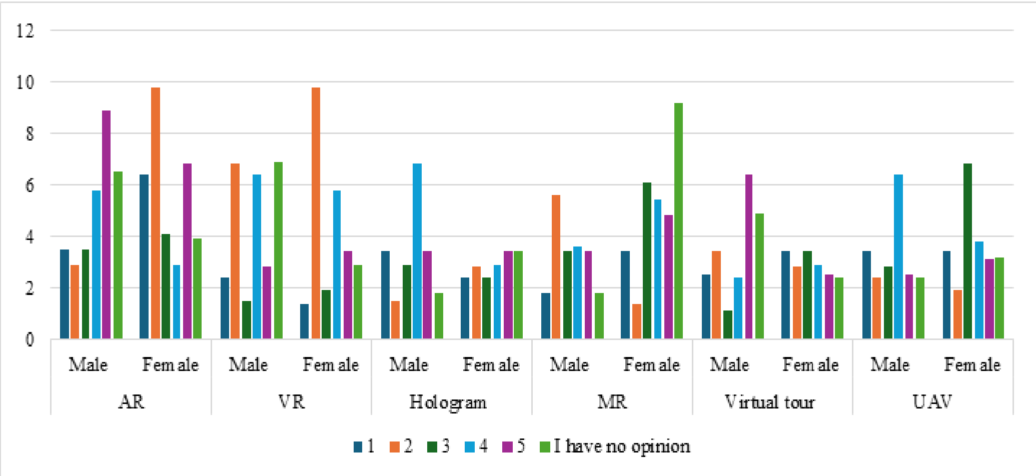
Does your area of study's educational process require the use of the technology you have learned?

It is evident from the data analysis that eXtended Reality 3D visualization approaches must be included into the educational process (Figure 12).

- The majority of respondents gave AR and VR a five-star rating, suggesting that both technologies are very necessary for their education;
- Although some ratings were somewhat lower, MR is also regarded as very vital;
- Although evaluations of holograms were a little more variable, the majority still considered them to be required or moderately necessary;
- With most reviews giving it a five-star rating, virtual tour technology is quite popular in education;
- UAVs were scored well as well; however, some respondents gave them somewhat lower rates;
- With average scores over 4, all technologies are regarded as being absolutely essential in education. Holograms (4.00) are viewed as somewhat less required than virtual tours (4.68) and virtual reality (4.62).

Figure 12

Potential need of using eXtended Reality visualization technology into the teaching and learning process (1-necessary, 5-essential)



Note. Elaborated by authors (2025).

The data presented indicates that respondents generally thought all of the technologies were valuable for their future employment. Nonetheless, there were some differences in the assessments by technology (Figure 13).

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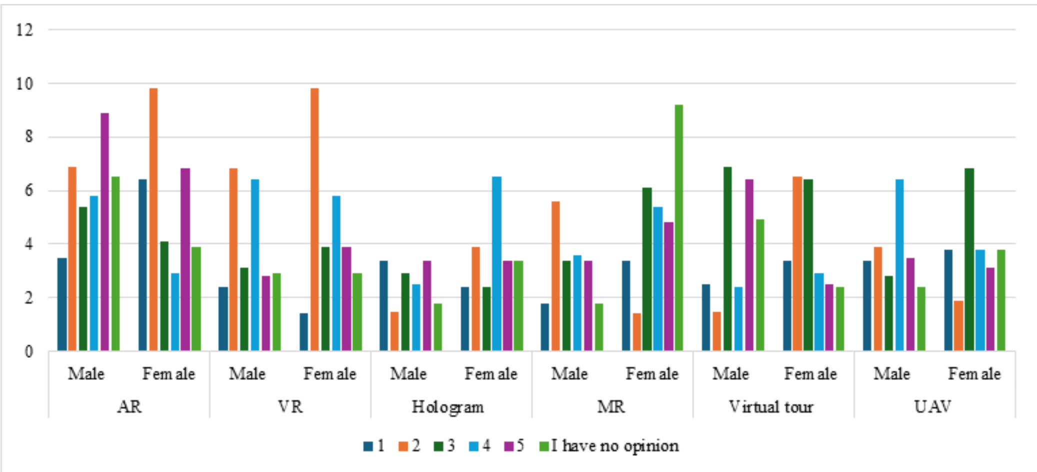
- All respondents gave AR a score of four or above, demonstrating how helpful they thought the technology was. This is due to AR's ability to blend the actual and virtual worlds, which makes it useful for a variety of land management and real estate applications;
- High scores were also given to VR, but little less than AR. The most immersive of the technologies described, this one may be useful for virtual real estate demos and other land management applications;
- MR, which blends aspects of AR and VR, received a favourable grade as well, despite some respondents giving it a 3;
- Opinions on the utility of holograms were the most diverse, with scores ranging from 2 to 5. This suggests uncertainty over the potential use of this technology in real estate and land management;
- The overwhelming majority of respondents gave virtual tours a rating of 5, indicating that they are useful. This is due to the fact that a virtual tour enables a person to explore an area without really moving about it;
- UAVs were found to be really helpful as well. Drones may be used for a variety of tasks in real estate and land management, including aerial property photography and building condition monitoring;
- With average ratings of 2.56 and 2.28, respectively, unmanned aerial vehicles (UAVs) and mixed reality (MR) are regarded as the most beneficial technology for real estate and land management. Virtual tours and holograms had lower value ratings (1.60 and 1.49, respectively).

Figura 13

eXtended reality visualization's possibilities for the respondent's future employment in real estate and land management



Note. Elaborated by authors (2025). 1 = completely useless, 5 = very helpful.

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All of the technologies included in the study were beneficial for land management, according to the data analysis. Nonetheless, some (such MR and holograms) received somewhat lower ratings than others (including AR, VR, Virtual Tour, and UAVs). According to the survey's overall findings, students thought the technologies they had investigated were beneficial and significant for their education.

CONCLUSION

All the technologies included in the study were beneficial for land management, according to the data analysis. Nonetheless, some (such MR and holograms) received somewhat lower ratings than others (including AR, VR, Virtual Tour, and UAVs). According to the survey's overall findings, students thought the technologies they had investigated were beneficial and significant for their education.

The essay discusses how AR, VR, MR, XR, and the metaverse may revolutionize cultural heritage teaching. The paper advances the discipline by offering a framework for incorporating XR into architecture education, which has the potential to transform design practice and pedagogy. This research examines how XR technologies are used in the business and makes important recommendations for reforming architecture education. These include expanding the course material, adopting dynamic, flexible evaluation techniques, and tying design themes to concerns that are pertinent to the industry.

Overall, the study demonstrates that students have a strong desire to learn more about this topic. It seems that AR is not yet extensively utilized in education or experienced in the typical student context, since the majority of students needed help recognizing the idea prior to the workshop. The phrase virtual reality, on the other hand, was familiar to most students, which could be because of its growing use in a variety of contexts, including gaming. Likewise, most students had not used the word MR, which refers to a very new and evolving technology. Due to their extensive use in pop culture and the media, holograms are a well-known idea. It is also common to be familiar with virtual tours since they are often used in real estate and tourism. Because UAVs are used in specialist military or technical industries like surveying, aerial photography, and filmmaking, there may be a lack of familiarity with them.

These activation techniques assist the institution, teachers, and students alike. These techniques lead to improved comprehension and information consolidation, more drive to study, and active involvement in class. Students' capacity for memory, collaborative work, creativity, and critical thinking may all be enhanced as a consequence. The university gains from increased student involvement in learning, improved attractiveness, the introduction of new forms of education in the form of workshops, and the development of organizational

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culture. Teachers can gain more job satisfaction, efficiency, and skill while working with Generation Z. Students are assessed in the Polish higher education system according to their capabilities, knowledge, and skills.

It was shown at the workshop that students' attitudes regarding contemporary 3D visualization technology may be altered by adding a single topic to the curriculum. Four major topics that need further future research have been identified by the research. First, an analysis of how AR, VR, and MR technologies are used and understood is necessary.

Therefore, many individuals need assistance in understanding and utilizing these technologies. Therefore, further research is needed to determine the specific areas where users struggle the most to develop effective teaching and assistance strategies. Second, evaluating the effectiveness of workshops and training in assisting users in becoming at ease and competent with AR, VR, and MR technologies is crucial. With this study's help, the most effective training methods to optimize the learning process will be discovered.

According to the study's findings, training in XR technologies has a beneficial effect on students' technical competency growth. In line with the notion that extensive training fosters technical competency, students demonstrated a notable increase in their theoretical understanding and practical proficiency regarding AR, VR, and MR technologies after the workshop. Students' attitudes toward the new technologies were also clearly altered by the session; their initial apprehensions and challenges with XR were replaced with increased confidence and drive to learn more about them and use them in their future jobs. There was confirmation of key study issues on the challenges of learning using XR. After the training, students' perceptions of these tools improved dramatically, and they had less difficulty using them than before they had trouble understanding and identifying modern technologies like AR and MR.

The training had a considerable effect on students' favourable views regarding using XR in future professional initiatives, according to the findings. It is confirmed that focused XR training can successfully prepare students for the challenges of today's job marketplace, where modern visualization and 3D technology are becoming increasingly important, by lowering stereotypes about the degree of difficulty and raising awareness of the advantages of these technologies in the study of engineering.

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