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The Potential Of Metaverse Technology In E-Learning: Case Of Engineering Students

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THE POTENTIAL OF METAVERSE TECHNOLOGY IN E-LEARNING: CASE OF ENGINEERING STUDENTS

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ABSTRACT

Metaverse technology integrates virtual and augmented reality, has significantly impacted many industries, and opened up new opportunities for educators and

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learners alike. This article focuses on its potential to transform e-learning, especially in engineering education, and highlights the importance of understanding engineering students' attitudes toward adopting new technologies. This study sheds light on the potential of e-learning in general, and the metaverse in specific, to engage and motivate students.

We conducted a quantitative online survey (n=120) to collect data from engineering students. The analysis of collected data explores and evaluates the students' awareness and acceptance of the metaverse in e-learning. Our results demonstrate that engineering students have a good awareness, a positive attitude, and motivation towards using new technologies and highlight a good opportunity for the metaverse to enhance engineering students’ online interactions and participation compared with traditional e-learning methods.

We have identified several challenges and opportunities in using the metaverse in e-learning, including the need for new competencies, specialized hardware and software, and data privacy and security concerns. The paper concludes with recommendations for future research, emphasizing the benefits, e-learning's potential, and challenges of the metaverse in e-learning.

1 INTRODUCTION

Metaverse is a virtual environment where people can exist under the rules defined by the creator (Hwang and Chien 2022), it gives the impression that everything is real and physical; people can interact with each other and digital objects in a shared space without being bound by physical limitations, creating a highly immersive and engaging experience.

Numerous industries, including business, education, and entertainment, stand to benefit greatly from this new technology. Metaverse has been gaining traction in recent years as a potential game-changer in the realm of e-learning (Zhang et al. 2022). The application of the metaverse in Engineering Education (EE) is an emerging research topic that has rapidly gained the interest of many researchers (Hwang and Chien 2022). In this paper, our focus is on exploring the potential acceptance of "the metaverse" as an educational tool by engineering students.

The use of the metaverse in the field of EE bridges the gap between theory and practice enabling students to visualize complex concepts and engage in hands-on activities that simulate real-world scenarios. It allows engineering students to collaborate with their peers in a virtual space, allowing them to share ideas and work together on specific projects. For example, students can design and test virtual prototypes, experiment with different materials, and simulate the behavior of physical systems in a controlled environment such as virtual laboratories (Kaddoura and Al Husseiny 2023). Indeed, instead of just applying theoretical concepts to practical EE problems, the metaverse offers an environment where students can see the immediate results of their actions, making it easier for them to connect theory to practice and pursue careers in engineering.

Headsets are the most commonly used hardware component for an immersive metaverse experience and are therefore considered in this context as metaverse technology. However, there are other hardware components available that can enhance the experience further. These include Holographic Displays such as room, wall, or table displays, as well as Fans and Wind Simulation, Vibrating or Motion Platforms, and Haptic Feedback Suits (Dwivedi et al. 2022). While these components are available, they may not be widely accessible to students at present.

This study aims to investigate engineering students' attitudes towards and willingness to consider the metaverse as an alternative to traditional learning methods. The key research questions addressed in this study are as follows:

RQ(1): What is the engineering students’ awareness and understanding of the metaverse?
RQ(2): Is there a relationship between demographic factors and the willingness of engineering students to adopt the metaverse for e-learning?
RQ(3): Does e-learning have an impact on the attitudes and behaviors of engineering students about adopting the metaverse?
RQ(4): Is there a gap between the theoretical perspectives of the metaverse and its practical implementation?

2 LITERATURE REVIEW

E-learning is the process of delivering educational content and training programs through various electronic media (Koohang and Harman 2005). It is facilitated by Virtual Learning Environments (VLE), such as “Learning Management Systems”, “Course Management Systems”, or “Personal Learning Environments” (Li 2022). VLE have emerged as effective means of delivering education as they provide safe and engaging learning situations (Adolf et al. 2019). Integrating metaverse as a new VLE can significantly enhance the e-learning experience by creating immersive learning environments that enable learners to interact with the material more engagingly (Zhang et al. 2022). Metaverse offers several advantages over traditional methods, such as gamification, diversity, equity, and inclusion, which can improve learner motivation and critical thinking (Hwang and Chien 2022), (Zhang et al. 2022).

Despite their advancements, the metaverse allows the collection of highly specific personal user data such as physical conditions and facial recognition, which can also lead to a higher risk of data breaches and privacy violations. Privacy and data security, as well as social and ethical considerations regarding intellectual property rights abuse, are essential issues of the use of the metaverse as a new VLS (Zhang et al. 2022), (Kaddoura and Al Husseiny 2023). Moreover, integrating metaverse in EE requires participants' awareness and willingness to accept change and explore new technologies (Hwang and Chien 2022), (Zhang et al. 2022).

Regarding students’ awareness and understanding of the metaverse, Won et al. (2022) (Won et al. 2022) investigated engineering college teachers’ and students’ experience of using the metaverse for non-face-to-face (NFF) teaching and found that they are generally willing to use virtual reality-based NFF teaching and learning shortly even if they had no prior experience with it. A recent study by Salloum et al. (2023) showed that the students were aware of metaverse technology and considered metaverse-based educational platforms to have had a significant impact on their learning outcomes. The study also suggests that the use of metaverse technology has the potential to revolutionize the delivery of higher education (Salloum et al. 2023).

Concerning the eventual relationship between demographic factors and the willingness of engineering students to adopt the metaverse for e-learning, the study of Özdemir et al. (2022) concluded that male participants had higher metaverse knowledge, attitude, and awareness levels than females. A positive and weak relationship was found between the participants' average daily social media usage time and digitalization attitude (Özdemir et al. 2022). Furthermore, the results of Aburbeian et al. (2022) (Aburbeian et al. 2022) showed that males demonstrated more interest in metaverse technology than females. Additionally, participants under the age of 20 showed a greater interest in metaverse technology compared to other age groups (Aburbeian et al. 2022).

Many studies (Salloum et al. 2023), (Adolf et al. 2019), (Ghobadi et al. 2022), (Kaur et al. 2020) have explored the impact of metaverse technology on student attitudes

and behaviors. They found that VR technology could increase students' interest, motivation, and engagement in learning. Kaur et al.(2020) investigated the effects of Augmented Reality (AR) on undergraduate students in electronics and electrical engineering and found that AR improved their attention, relevance, confidence, and satisfaction with the learning material in a classroom.

However, to the best of our knowledge, no dedicated study has explored the potential influence of demographic, behavioral, and attitudinal factors on engineering students' acceptance of the metaverse in e-learning. In this article, we aim to fill this research gap by examining the factors that affect engineering students' perceptions of the metaverse.

3 METHODOLOGY

3.1 Study context

In this article, we targeted opportunities to use the metaverse in the higher education sector for engineering students. To answer our research questions, we conducted, between February and April 2023, a quantitative online survey that was distributed to several engineering universities. We mainly investigated the awareness and satisfaction of engineering students regarding the adoption of new technologies, specifically focusing on the full immersion metaverse technology facilitated through specialised headsets.

We received 120 responses from engineering students. We took care to ensure that the students were fully informed about the purpose and utilisation of the data collected. We made it clear to them that the data would be used for research purposes. The participant's demography shows that 65% were male, while 35% were female. As shown in Figure 1, mechanical and computer sciences students have registered the highest participation with 33% and 30% responses respectively.

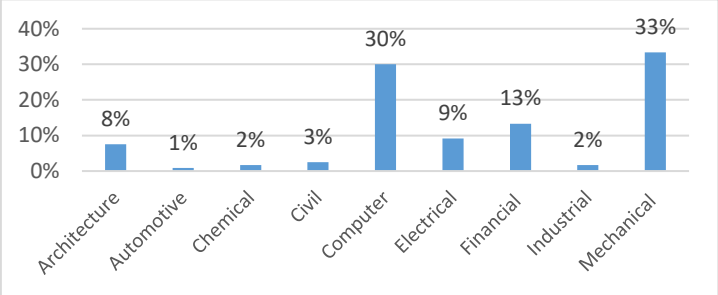

Fig. 1. Survey questions visualization for engineering majors' percentage

Out of the 120 respondents, the highest participation was registered by undergraduate students (48% of the total participants). Following them were master's (29%) and Ph.D. degree students (23%).

We got 33% of responses from ages 21 and 23, 33% of responses from ages above 26 years, 19% of responses from ages between 24 and 26 years, and 15% of responses from ages less than 21.

We have outlined our study's objectives, confidentiality policy, participant confidentiality, data storage and processing, and other ethical considerations in the survey's introduction section.

The questionnaire was conducted with closed questions that mostly used the Likert 5-point scale. We addressed the attitude of students regarding e-learning and new technologies and the use of metaverse in the education sector. Some examples of survey questions include:

> I think that e-learning services have a positive impact on a student's ability to listen and concentrate : Strongly disagree; Somewhat disagree; Neutral; Somewhat agree; Strongly agree.
> Are you interested in learning about the metaverse and its potential applications in e-learning? : Not interested at all; Not really interested; Somewhat interested; Yes, interested; Yes, very interested.

To gather feedback on our survey design, a pre-test was conducted with a group of eight students. Based on their feedback and ideas for improvement, the survey was further developed and finalized. The survey was then distributed to all engineering students through email.

To address our fourth research question (RQ4), we selected a subset of eleven students who had used the metaverse in their undergraduate senior project. We recorded their answers separately and compared them with those of the complete sample obtained in the principal survey.

For data analysis, we employed statistical analysis (T-test, ANOVA, and Kruskal-Wallis) and utilized several artificial intelligence classifiers, including Decision Tree (DT), Support Vector Machines (SVM), Random Forest (RF), Logistic Regression (LR), and Gradient Boosting (GB).

4 RESULTS AND DISCUSSION

4.1 Level of awareness, experimentation, and willingness to adopt the metaverse

Our first research question (RQ1) aimed to investigate the level of awareness and understanding of the metaverse among engineering students. The survey data indicated that 65% of the participants had heard of the term "Metaverse," while 20% had heard of either VR or AR but not both together. Only 15% of the participants had never heard about the metaverse. These findings align with the findings of Salloum et al. (2023) (Salloum et al. 2023).

Among the 85% of participants who had prior awareness of virtual and/or augmented reality, 56% of them had not experimented with metaverse before. This finding suggests that although a significant number of participants had prior knowledge of VR and/or AR, they were not necessarily familiar with the metaverse.

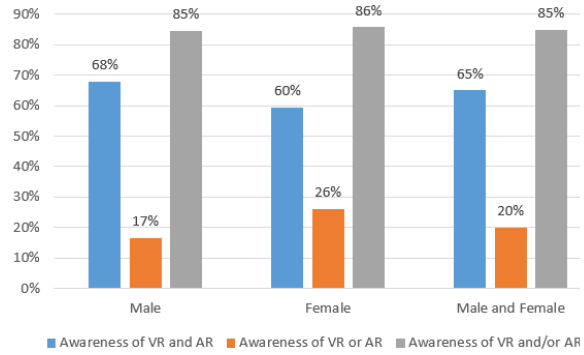

Fig. 2. Awareness of VR/ AR

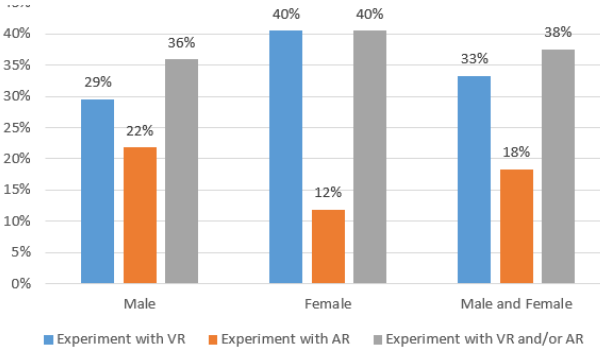

Fig. 3. Experimentation with VR/ AR

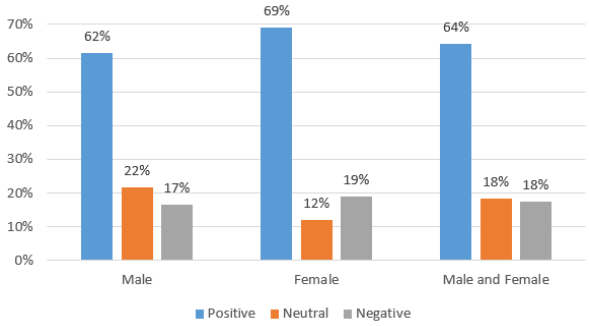

Fig. 4. Willingness to adopt the metaverse for e-learning

To further explore the distribution of awareness and experimentation of VR and/or AR regarding gender, figures 2, 3, and 4 present a description of the results. They provide a breakdown of the participant's gender and their level of awareness, experimentation, and willingness to adopt the metaverse.

4.2 Influence of demographic factors on engineering students' awareness, understanding, and willingness to adopt the metaverse

Our second research question (RQ2) aimed to gain a deeper understanding of the demographical factors that may influence the participants' level of awareness and understanding of the metaverse.

A statistical analysis using independent sample T-test for H0, H1 and H2, and Anova and Kruskal-Wallis tests for H3, H4 and H5 was performed to investigate the following hypotheses:

H0: there is a relation between gender and the metaverse's awareness level.
H1: there is a relation between gender and the experimentation of the metaverse.
H2: there is a relation between gender and the willingness of engineering students to adopt the metaverse for e-learning.
H3: there is a relation between the level of education and the level of awareness of the metaverse.
H4: there is a relation between the level of education and the experimentation of the metaverse.

H5: there is a relation between the level of education and the willingness of engineering students to adopt the metaverse for e-learning.

The results of the unpaired T-test showed that the p-values for H0, H1, and H2 were respectively 0.609, 0.855, and 0.212, all of which were greater than or equal to 0.05. Therefore, H0, H1, and H2 were rejected, indicating that there is no significant relation between the level of awareness, experimentation, and willingness to adopt the metaverse and gender. These findings differ from those presented by Özdemir et al. (2022) (Özdemir et al. 2022) and Aburbeian et al. (2022) (Aburbeian et al. 2022).

The ANOVA test showed that the p-values for H3 and H4 were, respectively 0.780, 0.816, greater than or equal to 0.05, meaning that these hypotheses were also rejected. However, the p-value for H5 was 0.021, which is less than 0.05, indicating that H5 was accepted. A similar result was obtained using the Kruskal-Wallis test.

Based on the analyzed sample, there was no significant relation between the level of awareness and the education level, nor between the experimentation of the metaverse and the education level. However, the willingness of engineering students to adopt the metaverse for e-learning was found to be directly correlated with the education level, with Ph.D. students showing the highest willingness to adopt e-learning compared to master and undergraduate students.

4.3 Relation between engineering students' Attitudes and their willingness to adopt the metaverse in Education

Our results indicate that engineering students hold positive attitudes toward the metaverse and are willing to learn more about it. A significant proportion of students (64%) expressed interest in exploring the use of the metaverse in education, as demonstrated in Fig.4. Additionally, 64% of the participants rated staying informed about new technologies as an extremely important aspect of their education. 44% of the participants thought that incorporating the metaverse into e-learning environments would enhance engagement and enjoyment, compared to only 3% who disagreed.

Our third research question (RQ3) aimed to further explore the relationship between students’ attitudes toward e-learning and their propensity to adopt the metaverse. To achieve this and better understand which factor affects the others we examined the potential correlation between the students' e-learning experience, their level of technological knowledge, and their willingness to integrate the metaverse into the education sector.

During the analysis stage, we employed the Pearson correlation coefficient to assess the relationship between different variables that could potentially affect the adoption of the metaverse in e-learning. We utilized multiple linear regression techniques with forward selection methods. The correlation coefficient should ideally deviate from zero, indicating a positive or negative relationship, and approach values of 1 or -1. For instance, a correlation between variables is considered weak if the absolute coefficient lies between 0.3 and 0.5, moderate if between 0.5 and 0.7, and strong if greater than 0.7.

	A -	B -	C -	D -	E -	F -	G -	H -	I -
A- Time spent online per day	1								
B- Level of understanding of new technologies	0.0	1							
C- Importance of staying informed about technologies	0.1	0.3	1						
D- Experience of internet weakness with e-learning	0.1	0.0	0.0	1					
E- Experience difficulty with e-learning tools	0.1	0.0	0.1	0.4	1				
F- E-learning improves listening and concentration	0.2	0.2	0.4	0.0	0.1	1			
G- Satisfaction with e-learning	0.0	0.2	0.2	-0.2	0.0	0.5	1		
H- Interest in using metaverse in e-learning	0.2	0.1	0.5	0.1	0.1	0.3	0.2	1	
I- Metaverse e-learning is more engaging	0.2	0.3	0.2	-0.1	0.0	0.2	0.3	0.5	1

Fig. 5. Corrolation Matrix

As shown in Figure 5, for instance, there is a weak positive correlation between the level of understanding of new technologies and the positive estimation of the metaverse as an engaging technique for e-learning. Additionally, a moderate positive correlation exists between the importance of staying informed about new technologies and the interest in using the metaverse in e-learning.

Additionally, we applied five well-known artificial intelligence classifiers (DT, SVM, RF, LR, and GB) using Python to predict the degree of "student's interest in using the metaverse in e-learning" based on other attitudes and behavioral features. The purpose of these classifiers is to provide a meaningful number (between 0 and 3) that accurately predicts the label "student's interest in using the metaverse in e-learning". We divided the data into training (80%) and testing (20%) sets.

Figure 6. displays the accuracy of predicting "student's interest in using the metaverse in e-learning" for each classifier. The Support Vector Machines classifier achieved the highest accuracy, with a good prediction accuracy of 87%, followed by the LR and RF classifiers at 80%, and the GB classifier at 73%. The DT classifier had the lowest accuracy, with only a 47% prediction accuracy.

The high accuracy of 87% achieved by the SVM classifier in predicting students' interest in using the metaverse for e-learning is significant. It means that the model was able to correctly classify 87% of the test data based on their attitudes and behaviors towards using the metaverse in e-learning. This indicates that the selected features (attitudes and behaviors of engineering students) have a strong influence on predicting students' interest in using the metaverse in e-learning. Therefore, this model can be used as a reliable tool to predict students' interest in using the metaverse for e-learning.

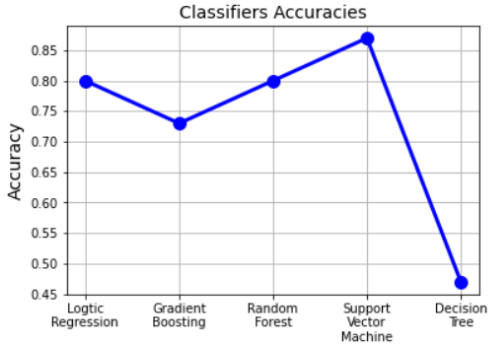

Fig. 6. Accuricies of AI classifiers

4.4 Experimented perception versus general knowledge perception

To answer RQ4 and fill the gap between theory and practice, the general survey used to collect data from random engineering students was compared with another survey gathering data from a group of 11 engineering students who had already worked on the development of a VR environment using Unity in their undergraduate senior projects. The 11 students were involved in three different groups to create three VR applications for academic purposes. The metaverse technology used to visualize these projects was mainly the Oculus Quest headset and controllers.

Data analysis of the selected sample compared with the general sample reveals a significant difference in the influence of the metaverse to offer a more engaging and motivated environment for learning. All users of the selected sample considered the potential of the metaverse to engage students and enhance e-learning involvement and interaction to be extremely important. Specifically, 73% of them reported that the main reason for engagement is the need for direct interaction with the educational virtual environment and the potential of metaverse technologies and tools to isolate the student from external distractions.

We conducted a statistical analysis using an independent sample T-test to investigate the following hypotheses :

> H6: there is a relation between the level of expertise and practice of the metaverse and considering metaverse-based e-learning environment more engaging and enjoyable than traditional e-learning methods.
> H7: there is a relation between the level of expertise and practice of the metaverse and considering that the metaverse has the potential to revolutionize the way students learn and practice their skills.

The results of the T-test showed that the p-values for H6 and H7 were less than 0.05. Therefore, H6 and H7 were accepted and statistically proven.

5 CONCLUSION

This study examines the potential influence of metaverse in EE and highlights the importance of understanding engineering students' attitudes toward adopting this technology. We surveyed to investigate engineering students' attitudes and demographical factors towards and willingness to adopt the metaverse in EE.

Our results illustrate that engineering students have a good awareness, positive attitude, and motivation towards using the metaverse in e-learning. We found that the only demographical factor that impacts the willingness of using the metaverse in e-learning is the student’s academic level. Also, we found a positive correlation between the willingness of staying informed about new technologies and the willingness to use the metaverse in e-learning. Moreover, the level of expertise and practice of the metaverse positively relates to considering metaverse-based e-learning environments more engaging and motivating than traditional ones.

Based on these results, educational engineering institutions could take advantage of the positive attitudes and motivations of engineering students towards using the

metaverse, and invest in programs that allow students to gain expertise and practice in using it. This could involve introducing the metaverse early on in the engineering curriculum and creating metaverse-based e-learning environments.

However, challenges still exist regarding the selection of materials to be included in the metaverse environment, as different engineering majors may require specialized metaverse technologies and configurations. Data privacy and security concerns also require further investigation. Moreover, although promising results were obtained in this preliminary study, we expect that a larger survey size will further enhance our findings.

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