Faculty and student perceptions of the metaverse in higher engineering education: A comparative study

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Abstract: *This study examines how students and faculty perceive the use of metaverse technologies in higher engineering education. Within the MAGURA project, 98 students and 35 faculty members participated in a shared immersive training seminar. We used a mixed-methods design: k-means clustering of student Likert-scale responses and thematic analysis of open-ended faculty statements supported by natural language processing. A pre-post comparison of faculty attitudes was also conducted to gauge change after the seminar.*
Three student profiles emerged: Highly Engaged Enthusiasts, Moderate Adopters, and Sceptical/Unconvinced learners. These profiles differed in motivation, conceptual understanding, and interest in further immersive training. The elbow method supported the choice of a three-cluster solution. Faculty views formed three corresponding groups: Pedagogical Innovators, Tech-Realists, and Cautious Sceptics, reflecting different balances between opportunity and feasibility. Faculty attitudes shifted positively after the seminar (mean score increased from 2.79 to 4.12 on a 5-point scale).
Students most often emphasised interactivity, gamification, and novelty, whereas faculty focused on structure, feasibility, and support needs. Despite these different priorities, both groups recognised the value of immersive environments for visualisation and learner engagement. The paper offers a two-sided analytical framework and practical recommendations for sustainable adoption, including hybrid delivery, faculty co-design, targeted professional development, and planning for institutional infrastructure.

Keywords: Metaverse, CAVE, Immersive environment, Virtual reality, Engineering education.

1. Introduction

Immersive tools such as virtual reality (VR), augmented reality (AR), and metaverse platforms are moving from demonstrations to limited use in higher education, including engineering. They promise more visual, hands-on work with complex concepts, which is why interest has grown in recent years (Mystakidis, 2022; Lee et al., 2021). At the same time, the evidence for when and how these tools add value is still uneven, and the costs in time, training, and infrastructure are not trivial.

In practice, the readiness gap is most visible between students and staff. Many instructors are cautious, often due to limited experience, unclear teaching scenarios, or lack of support (Selwyn, 2016; Park & Kim, 2022). Students are

https://doi.org/10.58503/icvl-v21y202636

generally curious and willing to try new formats, even without prior exposure (Hwang & Chien, 2023). This tension creates both resistance and an opportunity to rethink how we introduce and support immersive learning.

This study examines perceptions on both sides after a shared training activity delivered within the MAGURA project. Ninety-eight students and thirty-five faculty members participated in the same immersive seminar, then provided feedback. We analyse student survey data and open-ended faculty responses to identify where views converge, where they diverge, and what would help adoption in real courses.

Our aim is straightforward: to show what each group values, what concerns they have, and what kind of support they need. Based on these insights, we suggest practical steps such as training, collaboration with faculty, and clear curriculum use cases. These steps can help make metaverse tools part of everyday engineering education, rather than isolated experiments.

2. Theoretical background

Interest in immersive learning has accelerated in higher education, with virtual reality (VR), augmented reality (AR), and metaverse platforms used for more visual, interactive work with complex ideas. Reviews note both promise and limits: benefits often hinge on authentic tasks, course alignment, and the practicalities of implementation (Lin, Lee & Liu, 2022). A decade-scale overview similarly points to growing use of visualisation, simulation, and scenario-based activities-areas where immersion is most likely to help (Tsoy, Turgunova, & Baek, 2023).

Recent studies track outcomes and readiness. Work on AR/VR reports gains in targeted skills and digital literacy, but results vary with context and learner preparation (Prabakaran, Widiastuti, & Suryani, 2024). Readiness research suggests that students are generally open to metaverse-enhanced learning, while existing indices may need adjustment to capture this setting more precisely (Garbutt, Jones & Hill, 2023).

Engineering education adds its own constraints. Classroom examples illustrate the value of immersive visualisation, alongside practical hurdles such as staff training, time, and infrastructure (Abidin et al., 2023). Studies of teacher-student interaction in VR-enhanced lessons reach a similar conclusion: sound pedagogy and institutional support are as critical as the technology itself (Lytvynova & Soroko, 2023). Beyond tools, broader digital preparedness matters; future teachers report confidence with digital learning, yet still need focused support in areas such as cybersecurity and data protection (Latorre-Medina & Tnibar-Harrus, 2023).

Notable gaps remain. Much of the literature focuses on either students or faculty, not both, and single-method designs are common. Pre-post designs that test whether short training changes attitudes are rarer. The present study addresses these points by combining student surveys with faculty reflections, applying statistical clustering and thematic text analysis, and including a before-and-after comparison of faculty attitudes. The aim is to provide a clear, bounded view of what helps (and hinders) meaningful use of metaverse technologies in engineering education.

3. Materials and methods

The study used a mixed-methods approach to examine how students and faculty perceive immersive learning and Metaverse technologies. It was conducted in March 2025 during a structured training seminar at the Faculty of Engineering and Technologies, Trakia University – Yambol, as part of the MAGURA project.

A total of 98 undergraduate engineering students and 35 faculty members from engineering disciplines participated in the study. All participants attended a hands-on seminar that included work with a CAVE system and interactive virtual simulations designed for engineering education. For most participants, this was their first systematic exposure to Metaverse and CAVE technologies in an educational context. The survey did not collect detailed individual demographic data; however, all participants shared a similar academic and institutional environment. This common context allowed the analysis of perceptions formed through a shared immersive experience.

After the seminar, students completed a questionnaire that included Likert-scale items (from 1 to 5) and open-ended questions. The quantitative items focused on motivation, understanding of course content, engagement, and perceived career relevance. The open-ended questions allowed students to comment freely on possible applications and learning challenges. Faculty members completed two surveys, one before and one after the seminar. The first captured initial expectations and attitudes, while the second focused on reflections, perceived challenges, and potential applications in teaching.

Quantitative analysis of the student data began with descriptive statistics, followed by k-means clustering to identify engagement profiles. Principal Component Analysis (PCA) was used to visualise the clustering results. Relationships between motivation, understanding, and perceived career relevance were examined using correlation analysis. For faculty, a pre-post comparison was conducted on an item measuring overall attitudes towards immersive learning, with responses converted into numerical values.

Faculty open-ended responses were analysed thematically, supported by natural language processing. Text data were cleaned and standardised, then converted into vector representations using TF-IDF (term frequency-inverse document frequency). k-means clustering was applied to group responses with similar linguistic patterns. The resulting clusters were examined by the research team using key terms and representative excerpts, leading to the definition of thematically meaningful categories. The analysis was implemented using standard Python libraries, primarily scikit-learn.

This mixed approach provided a more complete understanding of the findings. By combining quantitative and qualitative data, the results could be examined from different perspectives and cross-validated across methods.

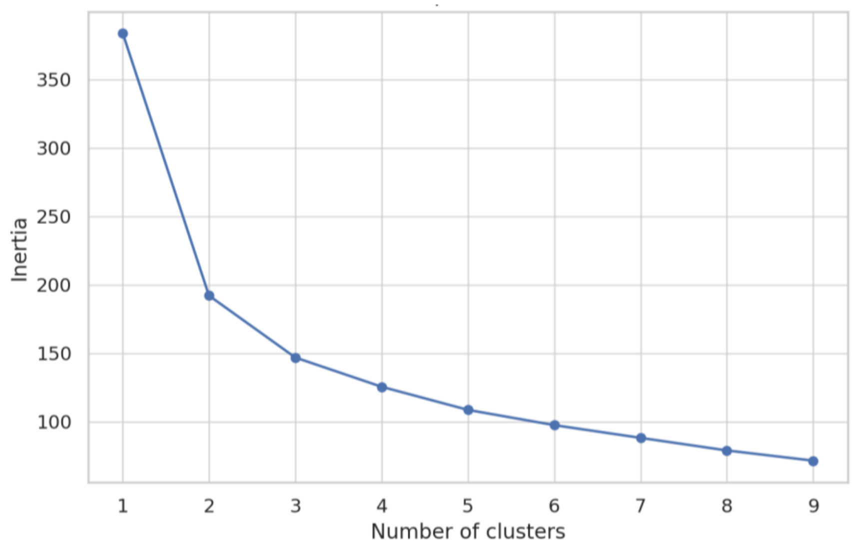

Figure 1. Elbow Method for Optimal Number of Clusters

The elbow method was used to identify an appropriate number of clusters for the k-means analysis. The method examines changes in inertia, which reflects how compact the clusters are for different cluster counts. In this study, the plot showed a clear inflection point at three clusters, after which further improvements were minimal. This supported the choice of three clusters as a balance between explanatory power and analytical simplicity. The same approach was applied to both student data and faculty responses.

The combination of methods and perspectives is a key strength of the study. Unlike many previous studies that focus only on students or only on faculty, this research examines both groups following the same shared training experience. In addition to survey scores, open-ended responses were analysed using NLP-based clustering, an approach still rarely applied in educational research. The study also tracked changes in faculty attitudes before and after the seminar, allowing the impact of even a short training intervention to be observed. The use of the Elbow Method further increased analytical transparency and reduced arbitrary decisions in participant grouping.

4. Results

4.1 Student profile clusters (quantitative analysis)

Cluster analysis of post-seminar student survey data revealed three distinct engagement profiles based on Likert-scale responses across four key dimensions: perceived conceptual understanding, motivation, interest in further metaverse-based training, and perceived career relevance.

Table 1. Student cluster profiles: mean scores by dimension

Cluster	**Concept Understanding**	**Motivation**	**Extra Training Interest**	**Career Relevance**
Highly Engaged Enthusiasts	4.80	4.60	4.68	4.75
Moderate Adopters	3.92	3.18	3.58	3.38
Sceptical or Unconvinced	2.50	1.56	2.06	2.38

Using k-means clustering and PCA visualisation, students were grouped into three categories:

- Highly Engaged Enthusiasts (Cluster 1): This group exhibited the highest mean ratings across all dimensions, particularly in motivation (M=4.60) and career relevance (M=4.75). These students also showed strong interest in continued participation in immersive learning experiences and preferred gamified and interactive elements;
- Moderate Adopters (Cluster 0): With average-to-high scores in perceived usefulness (M=3.92) and hybrid format preference, this group expressed openness to Metaverse tools but with more conditional enthusiasm;
- Sceptical or Unconvinced (Cluster 2): This smaller group reported low motivation (M=1.56) and limited belief in the relevance of immersive learning for their future careers. Their challenges centred on unfamiliarity with the tools and a lack of initial engagement.

As shown in Figure 2, the scatterplots summarise the pairwise relationships among motivation, conceptual understanding, and perceived career relevance. Trend lines are included to support visual comparison of the direction and strength of the patterns.

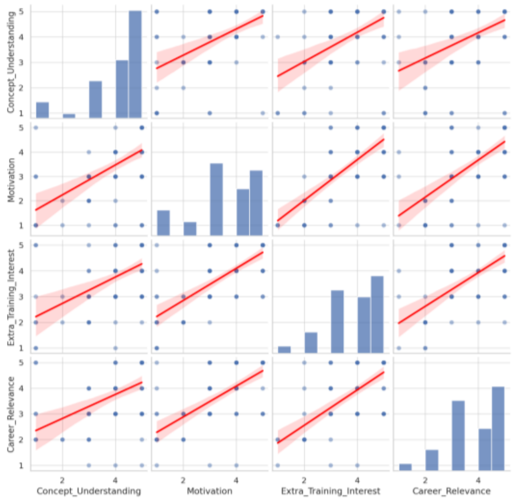

Figure 2. Pairwise scatterplots of student motivation, conceptual understanding, and perceived career relevance, with fitted trend lines

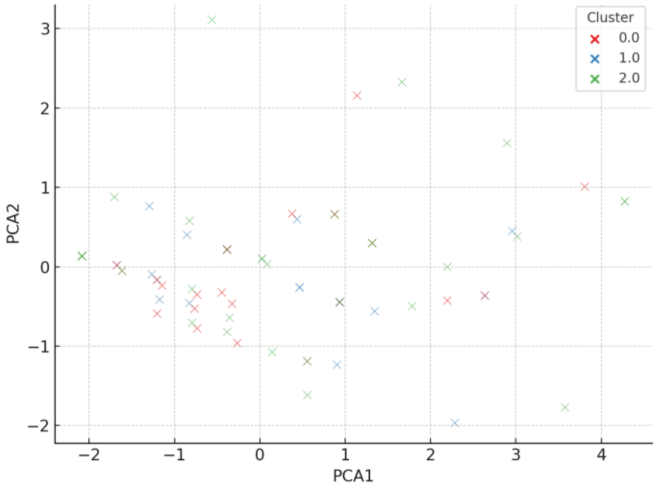

Figure 3. PCA-Based Student Cluster Visualisation. K-means clusters of students projected in 2D space using principal component analysis

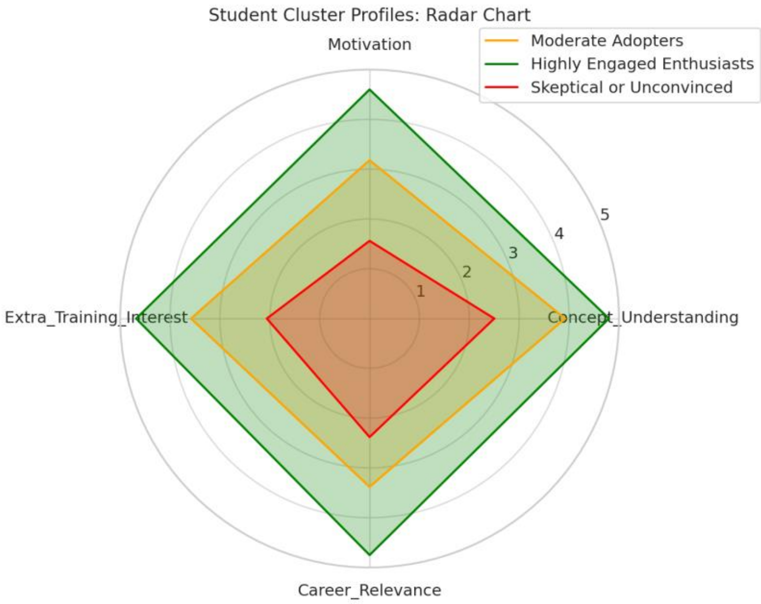

Figure 4. Radar chart of mean scores across four dimensions for the three student clusters

Figure 3 visualises the three k-means clusters in a two-dimensional PCA space (PC1–PC2). The plot provides an intuitive view of cluster separation and overlap in the reduced feature space.

As shown in Figure 4, the three clusters differ in their mean dimension scores. Highly Engaged Enthusiasts demonstrate uniformly higher ratings, Moderate Adopters occupy an intermediate position, and the Sceptical/

Unconvinced group reports lower ratings across dimensions. This pattern supports the interpretation that students' attitudes towards immersive technologies are heterogeneous.

4.2 Faculty response clusters (qualitative thematic analysis)

A parallel unsupervised text-clustering analysis was conducted on open-ended faculty responses using TF-IDF vectorisation and k-means modelling. The resulting three clusters illustrate a diverse range of attitudes and expectations towards immersive learning:

- Pedagogical Innovators (Cluster 0): Faculty in this group emphasised the instructional potential of metaverse tools for improving visualisation, engagement, and interactivity. Challenges included limited training and instructional design support, while expectations centred on fostering creativity and innovation in engineering education;
- Tech-Realists (Cluster 1): These respondents viewed immersive technologies pragmatically, recognising their practical value for safe experimentation and visualisation, yet voicing concerns about infrastructure costs, student preparedness, and selectivity in use;
- Cautious Sceptics (Cluster 2): This group acknowledged some benefits but expressed concerns about feasibility, including reduced faculty-student interaction, insufficient support systems, and uncertainty regarding the pedagogical return on investment.

Representative excerpts from each cluster illustrate the range of faculty readiness, with some calling for strategic integration and others advocating a more conservative approach.

Table 2. Faculty cluster comparison: key themes and attitudes

Cluster	**Engagement Level**	**Key Interests**	**Challenges**	**Support Needs**
Pedagogical Innovators	Positive and proactive	Interactivity, creativity, visualisation	Training, time investment, content design	Institutional incentives, design support
Tech-Realists	Conditional	Practical value, safe experimentation	Cost, staff capacity, student preparedness	Selective use, targeted training
Cautious Sceptics	Low to moderate	Basic visualisation, concept clarity	Communication gaps, feasibility concerns	Clear strategy, baseline institutional support

4.3 Student-faculty cross-cluster comparison

A side-by-side comparison of student and faculty clusters revealed both alignment and divergence. Table 3 summarizes the main points:

Table 3. Student–Faculty cross-cluster matrix: shared features and divergences

Student Cluster	Faculty Cluster	Shared Features	Key Divergence
Highly Engaged Enthusiasts	Pedagogical Innovators	Emphasis on interactivity and visualisation	Students want gamification; faculty seek structure
Moderate Adopters	Tech-Realists	Conditional acceptance	Students uncertain of value; faculty wary of cost
Sceptical or Unconvinced	Cautious Sceptics	Low confidence in readiness	Students cite motivation; faculty cite feasibility

These findings highlight the need for strategic alignment of expectations and implementation support.

4.4 Summary of faculty expectations and concerns

Analysis of faculty narratives yielded several recurring themes:

- Training Needs (33 mentions): A clear demand for structured onboarding, including both technical and pedagogical training;
- Cost and Equipment (29 mentions): Concerns about infrastructure investment and access to suitable hardware;
- Engagement Potential (29 mentions): Optimism about improved motivation and participation, provided tools are well-integrated;
- Pedagogical Integration (19 mentions): Questions regarding curriculum fit and instructional design;
- Student Readiness and Communication (low frequency): Some noted the risk of reduced interpersonal contact and uneven student preparation.

These themes emphasise the necessity of institutional support systems to ensure sustainable and effective integration of metaverse technologies in engineering education.

Table 4. Frequency of Recurring Faculty Themes. Ranked list of themes mentioned in post-seminar responses

Theme	Mentions
Training	33
Cost & Equipment	29
Engagement Potential	29
Pedagogical Integration	19

Theme	Mentions
Student Readiness	5
Communication Challenges	3
Technical Support	1
Time Constraints	1
Selective Use	0

4.5 Faculty attitude shift: Pre- and Post-seminar comparison

Faculty attitudes towards immersive learning technologies were compared before and after their participation in the Metaverse seminar. Pre-seminar responses were collected using a 5-point Likert-scale question measuring familiarity and openness. Post-seminar attitudes were inferred from corresponding qualitative descriptors and mapped onto the same scale.

The average faculty attitude score prior to the seminar was 2.79, indicating a neutral to slightly hesitant stance. After the seminar, the mean score increased to 4.12, reflecting a shift towards a clearly positive outlook. This suggests that even a short-term intervention—focused on exposure, hands-on experience, and discussion—can significantly influence instructors' perceptions.

This finding aligns with broader literature emphasizing the impact of guided training on faculty technology adoption (Park & Kim, 2022) and underscores the importance of experiential learning not only for students but also for educators.

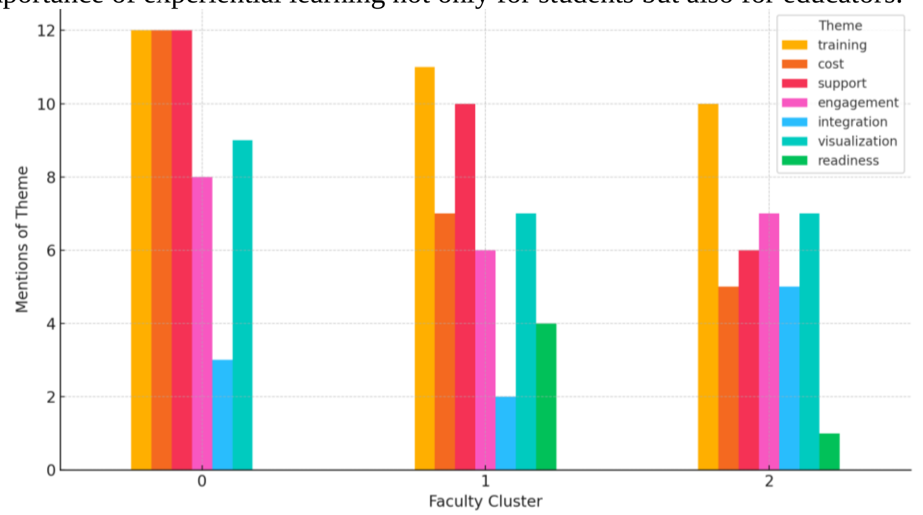

Figure 5. Faculty cluster-based thematic map (sampled open-ended responses per cluster)

5. Discussions

The comparative analysis reveals both clear alignment and important differences between student and faculty perceptions of immersive technologies in engineering education. Both groups recognise the potential of Metaverse environments to improve visualisation and engagement. At the same time, students show stronger enthusiasm and a greater focus on the learning experience itself. Faculty responses are more cautious and reflect concerns related to pedagogy, resources, and institutional readiness.

Limited prior experience with Metaverse technologies is a key factor in interpreting these differences. For many students and faculty members, the seminar was their first structured encounter with an immersive learning environment. This helps explain the clearly defined profiles and the strong initial reactions. Positive attitudes are linked to novelty and perceived pedagogical value, while more cautious or sceptical views reflect uncertainty about long-term use and practical feasibility. In this sense, the identified profiles represent differences in readiness to adopt the technology rather than stable personal traits. The absence of more detailed demographic variables limits deeper differentiation and points to directions for future research.

The findings should also be interpreted within the single-institution context of the study. Data were collected within one faculty and a specific project, which limits statistical generalisation to a wider population of students and educators. The aim of the analysis, however, was not population-level inference but the identification of analytically meaningful perception profiles formed after a shared immersive experience. From this perspective, the student and faculty clusters can be viewed as transferable typologies rather than fixed patterns tied to a single institution. Similar profiles may emerge in other engineering education contexts when immersive technologies are introduced under comparable conditions. The proposed analytical framework provides a foundation for future comparative and multi-institutional studies.

Particular attention should be given to the group of "Highly Engaged Enthusiasts." These participants show high motivation, positive attitudes, and a clear interest in further use of immersive technologies in education. They can be seen as early adopters of Metaverse solutions and play an important role in the initial stages of implementation. Through feedback, application ideas, and participation in pilot activities, they can support experimentation and adaptation. At the same time, their enthusiasm should not be treated as representative of all students. The findings highlight the need for a balanced approach that also considers the views of moderately engaged and sceptical participants. This points to a key limitation of the study, which captures short-term perceptions after a brief intervention, and underlines the need for longer-term observation.

The differences between the two groups have important implications for implementation. Faculty readiness emerges as a central factor, not due to resistance, but because of limited training, time, and structural support. Student enthusiasm can drive pilot initiatives, but it is not sufficient on its own for sustainable adoption. The presence of moderately positioned participants in both groups suggests opportunities for targeted interventions that could support wider acceptance. The results also show that even a short, well-designed training intervention can lead to meaningful changes in faculty attitudes when supported by a clear pedagogical framework and an enabling institutional environment.

6. Conclusion

This study offers a comparative view of how students and faculty perceive the use of Metaverse technologies in engineering education. Students show high engagement and interest, while faculty display a more cautious but generally positive stance shaped by concerns related to training, resources, and pedagogical fit. Cluster analysis indicates that both groups include supporters, moderate participants, and sceptics, although the reasons behind these positions differ. For students, novelty and direct experience are key drivers, while for faculty, institutional readiness and alignment with the curriculum play a central role.

The findings highlight that sustainable adoption of immersive technologies requires targeted institutional support. Structured training for faculty, collaborative course development, and phased implementation are essential. The study contributes a two-sided methodological framework that combines quantitative and qualitative analysis and enables clear identification of different perception profiles. The conclusions and recommendations presented here can support universities in planning strategies for integrating Metaverse technologies in ways that enhance educational quality and address the needs of both students and faculty.

Acknowledgements

The paper is part of the research project Metaverse Approach for a New Generation of Engineering Education and Collaborative Learning (MAGURA), within the framework of Project No. BG-RRP-2.004-0006-C02, titled 'Development of Research and Innovation at Trakia University in Service of Health and Sustainable Well-being'.

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