Exploring engineering students' perceptions of immersive learning: A mixed-methods post-seminar study

Veselina NEDEVA[1], Nely GEORGIEVA[1], Polina HÄFNER[2], Apostol TODOROV[1], Vasil HRISTOV[1]

[1] Trakia University, Faculty of Engineering and Technologies, Yambol, Bulgaria

[2] Karlsruhe Institute of Technology, Institute for Information Technology Management, Germany

veselina.nedeva@trakia-uni.bg

Abstract: *This study investigates engineering students' perceptions of immersive learning technologies following a structured hands-on seminar that introduced CAVE-based simulations, collaborative 3D environments, and digital-twin scenarios. Grounded in constructs aligned with technology acceptance and experiential learning frameworks, the study employs a mixed-methods design combining descriptive statistics, correlation analysis, and thematic coding of open-ended responses.*

Ninety-nine undergraduate engineering students completed a post-seminar survey assessing perceived usefulness, conceptual understanding, motivation, career relevance, hybrid-learning preference, and distraction. Results show high ratings for conceptual understanding and perceived usefulness, with strong correlations between career relevance, hybrid-learning preference, and perceived utility. Qualitative insights emphasise interactivity and visualisation as key pedagogical strengths, while highlighting technical constraints and equipment availability as prominent challenges.

Findings indicate that students view immersive environments as pedagogically valuable and professionally meaningful, provided that their implementation is supported by reliable infrastructure and coherent instructional design. The study contributes empirical evidence to ongoing discussions on simulation-rich and Metaverse-aligned engineering education, emphasising the need for scalable integration strategies and longitudinal evaluation.

Keywords: Immersive learning, CAVE, Virtual reality, Engineering education, Student perceptions, Educational technology, Mixed-methods analysis.

1. Introduction

Immersive and three-dimensional learning environments have transitioned from experimental demonstrations to increasingly viable components of engineering education. Their expansion aligns with broader pedagogical shifts towards spatial reasoning, interactive problem-solving, and scenario-based learning. Virtual reality, augmented reality, multi-user 3D spaces, and emerging Metaverse-aligned platforms now provide opportunities for learners to engage with engineering problems in ways that approximate authentic professional contexts. Recent reviews consistently report benefits when immersive technologies are

https://doi.org/10.58503/icvl-v21y202635

paired with coherent instructional design, including enhanced conceptual insight, improved spatial visualisation, and more authentic task engagement (Yang et al., 2024; Di Natale et al., 2024; Chua & Yu, 2024).

However, persistent limitations remain. The effectiveness of immersive learning depends on technological reliability, curricular integration, and the clarity of pedagogical guidance. Many studies highlight challenges involving scalability, ergonomics, and institutional readiness. While student reactions are generally positive, the foundations of this enthusiasm—and its relationship to perceived usefulness, motivation, hybrid-learning preference, and career relevance—are rarely examined in an integrated manner. Research comparing student and institutional readiness further suggests that student expectations may outpace implementation capacity (Qiu et al., 2023).

This study is conceptually informed by models of technology acceptance (Davis, 1989; Venkatesh et al., 2003) and experiential learning. Constructs such as perceived usefulness, motivation, satisfaction, and career relevance map well onto these frameworks, enabling a more structured interpretation of students' responses. By focusing on learner perceptions following direct exposure to immersive environments, the study aims to clarify how students interpret pedagogical value, how they differentiate short-term usability constraints from long-term relevance, and how these factors interrelate.

In March 2025, the Faculty of Engineering and Technologies at Trakia University organised a focused seminar exposing engineering students to CAVE-based demonstrations, collaborative virtual spaces, and digital-twin scenarios. This controlled event provided an opportunity to isolate student perceptions independent of ongoing curricular practices and institutional constraints.

The present study uses a mixed-methods design to integrate descriptive statistics, correlational analysis, and thematic coding of student reflections. It contributes to the literature by jointly examining perceived usefulness, conceptual understanding, motivation, satisfaction, hybrid-learning preference, and career relevance—constructs typically analysed in isolation. Through this integrated lens, the study seeks to support evidence-based, scalable strategies for embedding immersive technologies within engineering curricula.

2. Materials and methods

The study adopted a cross-sectional mixed-methods design to explore engineering students' perceptions immediately after participating in an immersive learning seminar. Quantitative constructs grounded in established technology-acceptance frameworks were combined with a qualitative thematic analysis intended to contextualise students' reflections in more depth. This integrated design enabled the examination of both numerical trends and the experiential nuances underlying student attitudes.

A total of ninety-nine undergraduate engineering students from the Faculty of Engineering and Technology at Trakia University took part in the study. All participants had limited or no previous exposure to immersive learning technologies within their formal coursework. Participation was voluntary and anonymous, and no incentives or academic credit were provided, ensuring that responses reflected authentic impressions of the learning activities.

The immersive seminar itself consisted of three interconnected components: CAVE-based simulations, multi-user 3D collaborative environments, and demonstrations of digital-twin workflows. These activities were selected to familiarise students with different forms of spatial, interactive, and simulation-rich learning. Across all components, the emphasis was placed on enabling students to navigate and manipulate engineering representations in ways that approximated real-world professional tasks requiring spatial reasoning and coordinated interaction.

Following the seminar, students completed a post-seminar survey designed to capture both structured ratings and open reflections. The quantitative portion assessed six constructs: perceived usefulness, conceptual understanding, motivation, career relevance, hybrid-learning preference, and perceived distraction (reverse-coded) - each measured on a five-point Likert scale. An additional three-level satisfaction item was included to provide a broader evaluative perspective. These constructs were chosen because they align closely with theoretical dimensions in technology-acceptance and experiential-learning models and therefore offer a coherent basis for interpreting the relationships among student perceptions. The qualitative portion of the survey invited students to describe the benefits and challenges of the immersive experience, as well as potential future applications they envisioned within the curriculum.

The survey was administered immediately after the immersive session to minimise recall bias and ensure that responses reflected students' direct, unmediated impressions. No identifying information was collected. The dataset was reviewed for completeness and internal consistency, and all responses were retained.

The quantitative analysis involved calculating descriptive statistics, including means, standard deviations and 95% confidence intervals for each construct, followed by Pearson correlation coefficients to examine associations among the key variables. Prior to computing correlations, assumptions of linearity and approximate distribution symmetry were assessed through visual inspection of histograms and scatterplots. Statistical significance was evaluated at the $\alpha=.05$ level.

To complement the quantitative results, open-ended responses were analysed using a codebook-driven thematic approach. Two independent coders undertook the analysis beginning with initial open coding, followed by the iterative development and refinement of thematic categories. Coding discrepancies were discussed until full agreement was reached, and intercoder reliability (Cohen's κ), was .78, indicating substantial agreement. The final thematic structure reflected four recurring areas of student commentary: interactivity, visualisation, challenges and expectations.

3. Results

3.1 Descriptive statistics

Students provided consistently positive evaluations of the immersive learning session across all constructs (Table 1). Conceptual understanding received the highest rating (M=4.04, SD=1.18), followed closely by perceived usefulness (M=3.98, SD=1.19). Motivation, career relevance, and hybrid-learning preference showed identical means (M=3.78), indicating moderate-to-high openness to the incorporation of immersive tools within engineering programmes (Table 1).

Table 1. Descriptive statistics of student ratings

Construct	Mean	SD	95% CI
Perceived usefulness	3.98	1.19	[3.74, 4.22]
Conceptual understanding	4.04	1.18	[3.81, 4.28]
Motivation	3.78	1.12	[3.56, 4.01]
Career relevance	3.78	1.14	[3.55, 4.00]
Hybrid preference	3.78	1.20	[3.54, 4.02]
Distraction (reverse-coded)	2.25	1.21	[2.01, 2.49]

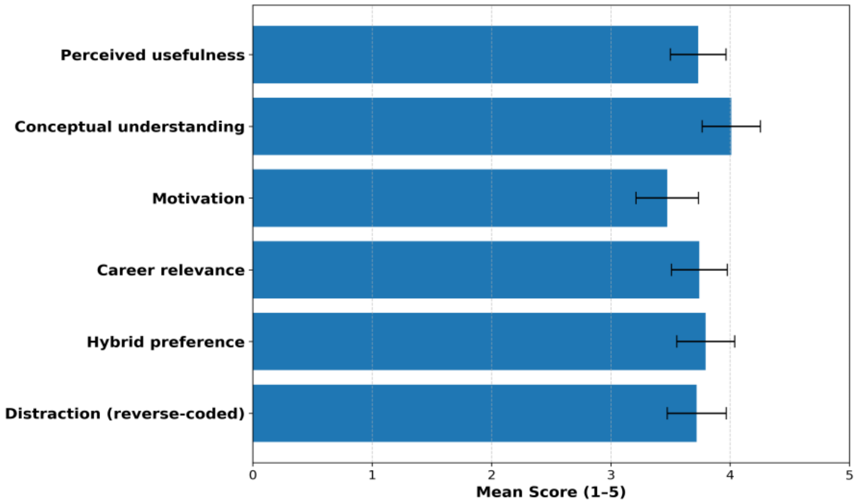

Figure 1. Summary of student perception ratings

Distraction (reverse-coded) yielded the lowest score (M = 2.25, SD = 1.21), suggesting that most students did not view the immersive environment as a barrier to focus.

These descriptive results indicate that students generally perceived immersive activities as learning-enhancing rather than novelty-driven, aligning with established findings in VR/AR engineering education research (Figure 1).

3.2 Correlational analysis

Pearson correlations revealed several strong and meaningful associations between constructs (Figure 2).

Figure 2. Correlation matrix of key constructs

Career relevance and hybrid-learning preference showed the strongest relationship (r ≈ .71), indicating that students who viewed immersive tools as professionally valuable were more likely to support their integration into blended learning formats.

Career relevance and perceived usefulness were also strongly associated (r ≈ .59), reinforcing the idea that students interpret immersive technologies through the lens of future employability and practical application.

Distraction (reversed-coded| and career relevance were positivly correlated (r ≈ .68), suggesting that students reporting fewer distractions also tended to report higher perceived career relevance.

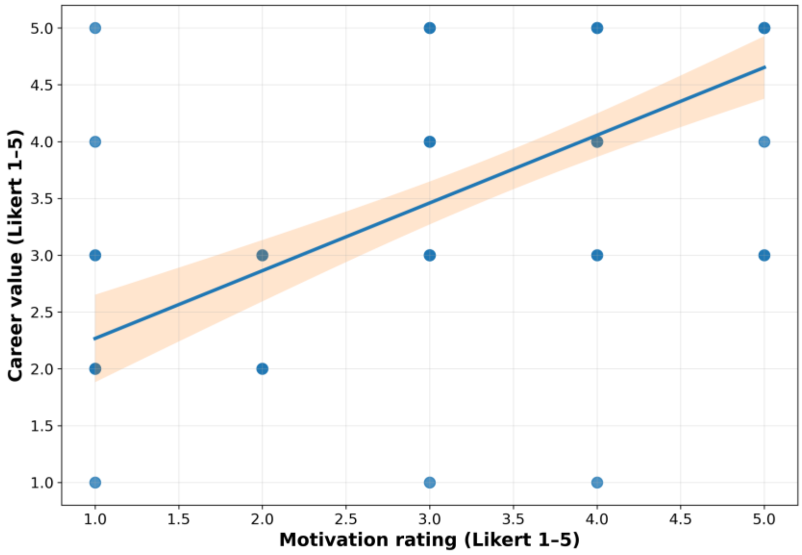

Figure 3. Motivation versus career relevance

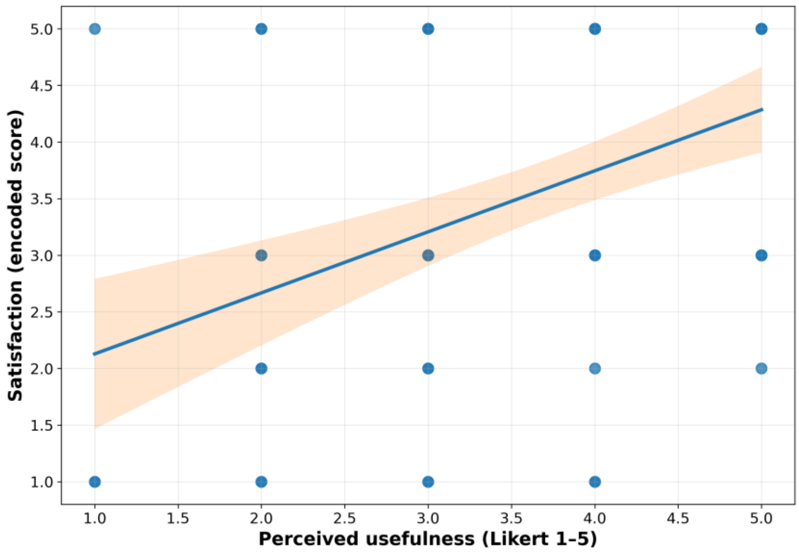

Figure 4. Perceived usefulness versus satisfaction

Motivation showed only moderate correlations with the remaining constructs ($r \approx .30–.40$ range), supporting the interpretation that motivation is multifactorial and shaped by broader experiential dimensions beyond usefulness or satisfaction.

Satisfaction correlated only weakly with usefulness and motivation, indicating that overall impressions are sensitive to implementation quality, system stability, and clarity of instruction.

Collectively, these patterns support a more nuanced understanding of how students position immersive learning within both academic and professional trajectories.

Motivation showed a moderately positive association with career relevance, indicating that students who view immersive technologies as professionally meaningful also tend to report higher levels of motivation. This pattern suggests that motivation is shaped not only by immediate engagement but also by perceptions of long-term applicability and future professional value (see Figure 3).

Satisfaction showed only a weak association with perceived usefulness, as indicated by the scattered pattern of data points. This suggests that students' overall impressions are influenced more by implementation quality—such as system stability, clarity of instructions, and ergonomic comfort—than by usefulness alone, a tendency that aligns with the qualitative comments provided by participants (see Figure 4).

3.3 Qualitative themes

The thematic analysis produced four overarching categories—interactivity, visualisation, challenges, and expectations—derived from 99 open-ended responses.

Interactivity: Students frequently described immersive environments as "engaging," "hands-on," and "more dynamic than traditional teaching." Manipulating 3D models and observing immediate changes were cited as key to maintaining attention and improving conceptual reasoning.

Visualisation: Visualisation was the second most prominent theme, with students noting that immersive scenarios made complex engineering processes easier to understand. Concepts normally confined to static diagrams appeared "clearer," "more realistic," and "easier to grasp in space."

Challenges: Despite the overall positive tone, students identified several obstacles:

- Occasional technical instability;
- Equipment limitations (e.g., insufficient devices for large groups);
- Physical discomfort or motion sensitivity for a minority of participants.

Notably, these challenges did not appear to reduce students' sense of long-term value.

Expectations and Future Application: Many students expressed a desire for greater integration of immersive tools in subjects involving system behaviour, design, and simulation. Comments suggested a readiness to use these tools beyond demonstration-level activities and within core engineering modules.

3.4 Integration of quantitative and qualitative findings

The qualitative insights reinforce the descriptive and correlational patterns. Interactivity and visualisation—two dominant themes—align directly with the high scores for conceptual understanding and perceived usefulness. Students exhibited the ability to distinguish short-term usability constraints from long-term relevance, which is consistent with the strong correlations linking career relevance to other constructs.

Students' open expressions of readiness for broader curricular integration further support the view that immersive technologies are perceived not merely as innovative add-ons but as credible components of modern engineering workflows. This integrated perspective provides a foundation for more structured adoption strategies within hybrid instructional models.

4. Discussion

The findings of this study demonstrate that engineering students perceive immersive learning environments as both pedagogically meaningful and professionally relevant. High ratings for conceptual understanding and perceived usefulness suggest that immersive tools have clear potential to support understanding of complex engineering phenomena, particularly those requiring spatial reasoning and dynamic visualisation. This is consistent with previous VR/AR research showing that immersive representations facilitate deeper comprehension when combined with coherent instructional design (Yang et al., 2024; Di Natale et al., 2024).

From a theoretical standpoint, the results align strongly with technology acceptance models (Davis, 1989; Venkatesh et al., 2003). The constructs of **usefulness**, **motivation**, **satisfaction**, and **career relevance** map closely onto perceived utility, behavioural intention, and facilitating conditions. The strong association between career relevance and hybrid-learning preference suggests that students perceived professional value of immersive technologies plays a central role in shaping support for their curricular integration. This finding indicates that immersive learning is not merely viewed as an experiential enhancement but as a tool aligned with emerging engineering practices, including simulation-rich workflows and collaborative digital modelling.

The qualitative findings reinforce this interpretation. Students described immersive experiences as interactive, engaging, and cognitively clarifying. These reflections connect directly to experiential-learning principles, where active manipulation, embodied visualisation, and situated problem contexts promote deeper learning. The dominance of interactivity and visualisation as themes aligns with the high mean scores for conceptual understanding and usefulness.

A notable result is the positive correlation between distraction (reverse-coded) and career relevance. Although initially counterintuitive, this pattern suggests that short-term discomfort or ergonomic issues did not diminish students' long-term view of immersive technologies as professionally significant. In theoretical terms, students appear capable of differentiating between immediate usability limitations (often tied to hardware maturity) and broader educational value. This aligns with findings in immersive-technology adoption research, where early-stage technical friction coexists with perceived strategic relevance.

Motivation's moderate correlations with other constructs further highlight its multifactorial nature. The weak association between satisfaction and usefulness indicates that implementation factors—such as system stability, device availability, and instructional framing—play a critical role in shaping overall impressions. This underscores the importance of robust infrastructure and pedagogical scaffolding in supporting adoption efforts.

Overall, the integrated quantitative and qualitative results reveal a student cohort that is highly receptive to the use of immersive technologies in engineering education. However, this enthusiasm is conditional: students expect reliable systems, structured guidance, and alignment with authentic engineering tasks. These expectations reflect a mature, academically grounded perspective that can inform strategic decisions about how immersive tools are embedded within engineering curricula.

5. Conclusion

This study demonstrates that immersive learning environments can meaningfully support engineering education when they are deliberately integrated into instructional design. Students reported high levels of conceptual clarity and perceived usefulness after engaging with CAVE-based simulations, collaborative 3D environments, and digital-twin demonstrations. These evaluations, together with strong links between career relevance, hybrid-learning preference, and perceived utility, indicate that students view immersive technologies not as temporary novelties but as tools connected to emerging engineering practice. Qualitative reflections further emphasised the value of interactivity and visualisation for understanding complex concepts, while also identifying practical concerns related to technical stability, equipment availability, and ergonomics.

Although these findings offer important insights, they reflect the perceptions of a single cohort in a controlled, short-term context and rely on self-reported data, which limits broader generalisation and does not capture long-term learning effects.

Taken together, the results suggest that immersive environments hold considerable promise as components of simulation-rich and hybrid engineering curricula, provided they are supported by reliable infrastructure and clear pedagogical framing. Future work should extend these findings through longer-term studies and cross-context comparisons to better understand how immersive technologies can be scaled and sustained in engineering education.

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'.

REFERENCES

Chua, H. W. & Yu, Z. (2025) A systematic review of the Metaverse in formal education. *Journal of Applied Research in Higher Education*. 17(5), 1850–1868. https://doi.org/10.1108/JARHE-04-2024-0162.

Davis, F. D. (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*. 13(3), 319–340. https://doi.org/10.2307/249008.

Di Natale, A.F., Repetto, C., Costantini, G., Riva, G., Bricolo, E. & Villani, D. (2024) Learning in the Metaverse: Are University Students Willing to Learn in Immersive Virtual Reality? *Cyberpsychol Behav Soc Netw*. 27(1), 28-36. 10.1089/cyber.2022.0395. PMID: 38197837.

Di Natale, A. F. et al. (2024) *Education and Information Technologies*. 29, 14749–14768. https://doi.org/10.1007/s10639-023-12436-7.

Qiu, Y., Isusi-Fagoaga, R. & García-Aracil, A. (2023) Perceptions and use of metaverse in higher education: A descriptive study in China and Spain. *Computers & Education: Artificial Intelligence*, 5, 100185. https://doi.org/10.1016/j.caeai.2023.100185.

Venkatesh, V., Morris, M. G., Davis, G. B. & Davis, F. D. (2003) User acceptance of information technology: Toward a unified view. *MIS Quarterly*. 27(3), 425–478. https://doi.org/10.2307/30036540.

Yang, C., Zhang, J., Hu, Y., Yang, X., Chen, M., Shan, M. & Li, L. (2024) The impact of virtual reality on practical skills for students in science and engineering education: a meta-analysis. *International Journal of STEM Education*. 11, 28. https://doi.org/10.1186/s40594-024-00487-2.