From Awareness to Competency: The Impact of a Structured Intervention on IT Students' Understanding of the Metaverse

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***Abstract*—This study examines a structured intervention at a Middle Eastern university. It aims to enhance undergraduate Information Technology (IT) students' comprehension and competency with the Metaverse. With immersive technologies still emerging in the region, the study targeted five core dimensions: conceptual understanding, tool familiarity, perceived academic benefits, ethical awareness, and reduction of usage-related challenges. Using a pre- and post-test design with 60 participants, the intervention yielded statistically significant improvements across all dimensions ($p < 0.001$). The greatest gains were observed in tool familiarity ($M = 1.41$, $t = 28.05$) and ethical awareness ($M = 1.07$, $t = 21.29$), highlighting the intervention's impact on both technical and critical thinking competencies. This study contributes to the growing body of empirical evidence on Metaverse integration in undergraduate IT education. It was implemented at a Middle Eastern university by presenting a model that may be adapted and tested elsewhere for competency development. It also identifies pedagogical strategies that, in this cohort, facilitate meaningful engagement with immersive environments. The findings may be relevant to similar institutions in early adoption phases, offering preliminary, context-specific insights for curriculum design and digital transformation in IT education. By addressing this gap, the study provides evidence on how Metaverse adoption can be integrated into IT higher education, and offers context-specific insights from a Middle Eastern setting.**

***Keywords*—Metaverse, immersive learning, virtual reality, education**

I. Introduction

The fast development of technological devices for teaching has presented a new way of interactive and immersive learning [1]. One of the most disruptive technologies on the horizon is the Metaverse, a virtual space combining Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR) increasingly integrated into core areas such as finance and education [2, 3]. Even though the potential for the Metaverse to revolutionize education has been widely discussed, empirical evidence on its effectiveness, particularly in the context of higher education, remains limited. This study assesses the impact of Metaverse integration on Information Technology (IT) students' academic experiences. The evaluation uses a pre-test and a post-test. It provides a pioneering empirical examination of Metaverse integration in IT higher education within a Middle Eastern context.

The study addresses several research questions:

- To what extent does the structured instructional intervention enhance IT students' conceptual understanding of the Metaverse?
- Does the intervention significantly improve students' familiarity with Metaverse related tools, their perceived academic benefits, and awareness of associated ethical considerations?
- Does the intervention lead to a measurable reduction in the challenges and barriers faced by students when engaging with Metaverse technologies in an academic environment?

The hypothesis of this study is that a structured Metaverse-focused intervention will enhance students' understanding of Metaverse concepts. The intervention is expected to improve familiarity with related tools and applications. It should also increase awareness of ethical issues. In addition, perceived academic benefits are expected to rise, while learning-related challenges decrease. More specifically, the study tests the following hypotheses:

- H_0 (Null Hypothesis): "There will be no significant difference in students' understanding of Metaverse concepts, familiarity with Metaverse tools, perceived academic benefits, awareness of ethical considerations, or reduction in usage-related challenges before and after the instructional intervention."
- H_1 (Alternative Hypothesis): "The instructional intervention will result in a significant improvement in students' understanding of Metaverse concepts, familiarity with Metaverse tools, perceived academic benefits, awareness of ethical considerations, and reduction in usage-related challenges."

Despite its potential, the Metaverse faces several obstacles:

- Cost: High VR equipment costs are a major obstacle to VR access and availability in education [4].
- Technical Issues: Hardware or software malfunctions can disrupt instruction and the proper operation of VR in classroom settings [5].
- Adoption and Integration of Technology: According to recent studies [6, 7], There are notable obstacles to adopting Metaverse technologies in higher education, with resistance to change and broader societal influences as primary challenges. Researchers propose strategies to address these barriers, emphasizing that overcoming them

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is essential to improving the effectiveness and long-term impact of Metaverse applications in university teaching.

- Health Concerns: Prolonged exposure to virtual reality has been linked to health issues such as motion sickness and fatigue. Consequently, the long-term implications of immersive technologies need to be considered carefully [8].

Integrating VR and the Metaverse into education necessitates robust ethical guidelines to address data privacy, access, and fair implementation. As stressed by Anastasovitis and Roumeliotis [9], it is crucial to build equal virtual worlds capable of responding to the needs of diverse groups, thus ensuring accessibility and inclusion. Similarly, Durak *et al.* [10] raised ethical caveats with regard to Extended Reality (XR) technologies adopted by society, including material disparities and the digital gap. Overall, these ethical issues require large-scale training programs to mitigate the potential hazards and help provide a safe and healthy virtual environment.

Although prior work often reports benefits of immersive and Metaverse learning, rigorous experiments could show mixed or null effects on achievement. Additionally, researchers caution against equating presence or motivation with learning. For example, Parong and Mayer [11] found that students learning via a well-designed desktop slideshow outperformed those in immersive VR on posttests. The discrepancy was mitigated only when a generative strategy (summarizing) was added to VR. Similarly, Makransky *et al.* [12] reported that adding immersive VR to a lab simulation increased presence but yielded lower learning than a desktop version.

Makransky and Lilleholt [13] shows that VR's effects on outcomes are often indirect—via effect, motivation, and usability—rather than direct. This underscores design-sensitive pathways from immersion to learning. Hamilton *et al.* [14, 15] and Radianti *et al.* [14, 15] concluded that while many studies favor Immersive Virtual Reality (IVR), a nontrivial share finds no significant differences, and a few report negative effects. These reviews also note short interventions, small samples, and scarce delayed tests. Makransky and Petersen [16] (Context-Aware Multiple Instance Learning (CAMIL)) likewise predicts benefits only when cognitive load and self-regulation are managed. Otherwise, high immersion can overload working memory and depress performance.

Taken together, the above perspectives justify our conservative claims about generalizability and our emphasis on instructional design (e.g., segmentation, generative prompts) when interpreting gains observed in our single-institution IT cohort.

While immediate engagement gains are promising, three areas require further attention [17–21]: longitudinal outcomes and cross-institutional generalizability, design moderators that determine when immersion supports learning, and implementation issues such as cost, teacher preparation, and accessibility. Addressing these gaps calls for large-scale, multi-site studies that combine adoption-model insights with experimental tests of instructional design and process measures like motivation, cognitive load, and usability.

Since this integration is still in its early stages, concerns about long-term effects arise, especially across diverse contexts and resource-limited environments. Some challenges have not been addressed adequately and warrant further investigation. Yet, challenges remain in scalability, teacher preparation, infrastructure, and resource availability.

Section II presents a comprehensive review of existing literature related to educational improvements through the integration of new technologies. Section III discusses the methods of the research in detail, encompassing the design and implementation of the educational framework to be evaluated. In Section IV, statistical analysis of educational improvement is presented, demonstrating the impact the proposed approach had on students' performance and their engagement. The paper concludes in Section V, summarizing the key findings and offering further suggestions on conducting another related research.

II. Literature Review

A. *Theoretical Foundations of Immersive and Collaborative Learning*

Examining how immersive technologies, such as the Metaverse, affect education can be better understood through established learning theories. One such framework is ARCS Model of Motivation [22], which identifies four critical elements for sustaining learner motivation: Attention, Relevance, Confidence, and Satisfaction. The Metaverse environment in this study captured learner attention through its engaging visual and interactive features, while its alignment with real-world IT applications ensured relevance. Confidence and satisfaction were promoted through interactive tasks, timely feedback, and clear goals, all of which are core to the ARCS framework.

Another key theory is Flow Theory [23], which describes an optimal learning state where individuals become deeply immersed in an activity. Flow occurs when learners face tasks that are challenging yet matched to their skill levels. In the simulation employed in this study, task difficulty increased progressively, controls were user-friendly, and participants received instant feedback. These elements, when combined, support a state of flow and increase learner engagement.

This study also gains from collaborative learning theories, especially the Zone of Proximal Development [24], which highlights the impact of social interaction and scaffolding in driving cognitive growth. Within the Metaverse-based workshops, students operated in teams, regularly exchanging perspectives and jointly navigating tasks in the virtual environment. This interactive framework did not only boost conceptual understanding, but also enabled the integration of peer engagement into the process.

On the technical side, instructional design elements like narrative structuring, instantaneous feedback, and deep immersion played significant roles in optimizing the learning experience. Meanwhile, real-time feedback mechanisms enabled students to rapidly reflect on their actions and make tactical adjustments. Immersion within the Metaverse elevated the participants' sense of presence—being psychologically "inside" the environment—which has been linked to stronger knowledge retention and more meaningful learning [25]. In combination, these features deliver a well-rounded, evidence-based model for maximizing the efficacy of technology-enhanced education.

B. Metaverse in Education: Applications, Outcomes, Engagement, Design, and Evidence

The studies discussed take a close look at how education can be shaped by both technology and environmental elements. For example, Fayyoumi *et al*. [26] investigated the perspectives of faculty members in Jordanian universities regarding blended learning. While the responses indicated only moderate satisfaction, there was a notable consensus on the necessity for professional training—especially in digital tools and even augmented reality—to genuinely support faculty engagement. Hanandeh *et al*. [27] evaluated the serious game "Help!" and its effects on motivation and achievement among undergraduate special education majors. The findings pointed toward increased motivation and engagement, which, interestingly, translated into improved academic outcomes through collaborative gameplay. Additionally, Hijazeena *et al*. [28] recognized the significance of e-learning in enhancing educational quality within Jordan's higher education sector. Of particular importance were institutional support and alignment with learners' needs; these were identified as essential components in realizing effective academic results. Finally, Sbaih *et al*. [29] analyzed university students' self-learning abilities using innovative technologies, underscoring the importance of digital adaptation in fostering autonomous learning and improving academic outcomes.

Complementing these findings, the Metaverse has been a transformational tool in education, as it allows students to experience real-world scenarios in a controlled, interactive environment. Refs. [30–32] prove that it is effective in promoting active learning and developing practical skills. The major drawbacks remain the high cost and safety concern for large-scale scalability [4].

Overall, the following recent work clarifies adoption drivers and boundary conditions for meta-education in higher education. Using an extended decomposed theory of planned behavior, Al-Adwan *et al.* [17] reported attitude, social influence, and perceived behavioral control as key antecedents of intention, with perceived enjoyment, herd behavior, autonomy, and innovativeness also contributing. Complementing this, Al-Adwan and Al-Debei [18] integrated Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) with Personal Innovativeness in Information Technology (PIIT) among Generation Z (Gen-Z) students and found that all UTAUT2 determinants, except social influence, can significantly predict intention; PIIT exerts additional direct and indirect effects.

Maghaydah *et al.* [19] indicate the dominance of the Technology Acceptance Model (TAM) or the Unified Theory of Acceptance and Use of Technology (UTAUT) frameworks and frequent Partial Least Squares Structural Equation Modeling (PLS-SEM) usage in Metaverse-education research [33]. Nevertheless, effectiveness evidence remains inconsistent. In vocational contexts, immersive VR appears to boost motivation participants' perception of their own learning, but those subjective gains don't always translate into immediate, measurable improvements [20]. Faculty members tend to respond positively toward VR integration overall, though they frequently stress the need for more robust institutional backing and clearer, more practical implementation strategies. So, while the technology holds promise, its actual impact is still up for debate [21].

Clearly, there is a growing body of research highlighting the benefits of Metaverse in education, from improving immersive learning and bringing more engagement to increasing skill acquisition.

- Engagement and Motivation: The immersive nature of the Metaverse is notable. It increases student engagement in the learning process. It motivates intrinsic motivation and active participation in the educational settings of this environment [34–36].
- Retention and Recall: Recent studies indicate that experiential learning in the Metaverse can significantly enhance long-term retention and recall. This mode of learning, which emphasizes activity and immersion, may offer notable advantages compared to more traditional, lecture-based teaching approaches [37, 38].
- Skill Development: The Metaverse offers remarkably realistic simulations, such as those in surgery or engineering, enabling users to enhance their critical thinking and problem-solving abilities in a controlled, immersive environment [31, 32, 35, 39, 40]. Further, these studies demonstrated that nursing students exhibit substantial readiness, heightened awareness, and notably positive attitudes regarding the integration of Metaverse technology into their educational experiences. This indicates strong potential for these future professionals to actively influence the ongoing evolution of e-learning within the healthcare sector.

The Metaverse advances virtual reality as it enables collaborative, interactive learning environments. These environments enhance engagement and participation. It can be noted that VR technologies establish immersive, interactive frameworks that serve as a foundation for Metaverse-driven educational approaches. For example, Hakeem *et al*. [41] examined the Active Learning with Holo-Kid (ALHK) system, highlighting its use of gesture-based controls and 3D holography to construct dynamic educational spaces. Such platforms enable real-time interaction and promote effective teamwork among students. These studies indicate that integrating the Metaverse can significantly enhance collaborative learning and student interaction. However, practical limitations concerning usability and accessibility need to be addressed prior to widespread adoption in mainstream education.

A strong narrative framework, immediate feedback, and interactive engagement are key to capturing and maintaining user attention in VR-based educational experiences [25, 42]. These design elements support motivation by providing contextual relevance and timely support. Such features are critical for sustaining attention and deepening conceptual understanding.

Immersive learning, particularly through VR, has demonstrated notable advantages across various educational domains, which may outweigh its disadvantages:

- Merchant *et al*. [31] conducted a meta-analysis and found that VR integration often leads to superior instructional outcomes, regardless of education level.
- Mazhar and Rifaee [34] attributed much of the effectiveness of VR to its immersive and highly interactive environment, which actively engages learners.
- Yang *et al*. [36] highlighted the role of VR in technical

education, emphasizing how it effectively connects theoretical concepts to real-world applications.

- Salameh *et al*. [32] documented statistically significant improvements in student satisfaction, self-confidence, and overall performance when VR simulations were combined with traditional teaching methods.

The present study investigates whether VR-based applications increase IT students' participation and retention in learning. By providing a secure, controlled, and engaging setting for practical exercises, this research aims to generate insights that could be beneficial in similar educational contexts. A comparative analysis of emerging educational technologies and their impact on learning is shown in Table 1.

Table 1. Comparative analysis of emerging educational technologies and their impact on learning

Ref.	Tech.	Area	Findings	Challenges
[34]	Virtual Reality	Efficacy of VR in Education	VR enables safe, controlled, and interactive learning experiences, enhancing engagement and individual learning needs.	High costs and technical challenges in implementing VR in educational settings.
[32]	Virtual Reality	Efficacy of VR in Nursing Education	There was a statistically significant improvement in satisfaction, self-confidence, and performance because of using VR simulation in practical nursing courses.	High costs and technical challenges in implementing VR in educational settings.
[41]	Metaverse, Omniverse, Extended Reality	Inclusion and Accessibility in Virtual Worlds	Virtual worlds have the potential to enhance accessibility in education and lifelong learning through immersive and inclusive environments.	Accessibility and integration challenges in combining virtual and real-world elements.
[41]	3D Holography, Leap Motion Gesture Interaction	Elementary Education	ALHK application enhances engagement and comprehension by combining holography with gesture interaction. Significant improvement observed.	Scalability issues, limited multi-user interaction, and need for broader age range applicability.
[43]	Augmented Reality	Teacher Training in Social Sciences Education	AR improves didactic experiences, supports diversity outreach, and aligns with universal design for learning, with a focus on social sciences.	Lack of widespread teacher training and resource availability for AR integration in classrooms.
[10]	Extended Reality	Science Education	XR can be a viable alternative to traditional classrooms. Teachers found XR helpful for creating engaging and practical lesson plans.	Teacher training gaps, resource limitations, and challenges in adapting XR for different educational contexts.

III. Materials and Methods

A. Participants and Tools

This study employed a one-group pretest-posttest design, which is widely used in educational research to assess immediate learning gains from interventions [44, 45]. A paired-samples t-test was selected to assess within-group changes over time. The study sample comprised 60 undergraduate students enrolled in IT-related programs, with a focus on the technological, ethical, and societal aspects of the Metaverse. Among the participants, 33.3% were from the Software Engineering program, while the remainders were from Computer Science, Information System, and related fields, as shown in Fig. 1. Participants were selected from second- and third-year cohorts. Gender data were not collected. The majority were average undergraduates aged 19–22. The total sample size (n) of 60 students is consistent with prior VR and immersive education research, where individual studies often included between 30 and 80 participants [31]. For example, Thomann *et al.* [20] reported n = 65 in their study of immersive VR for vocational education, and Mazhar *et al.* [46] used n = 60 to evaluate VR communication interfaces. Given the within-subjects design, this sample was sufficient to detect medium effects at $\alpha = 0.05$ with statistical power above 0.80. Pre-test and post-test were designed to assess participants' knowledge of the definitions, usage, and benefits of the Metaverse, utilizing a 5-point Likert scale [47]. Instrument details will be provided in Section III.C.

This study incorporated the use of SimLab, a virtual reality platform for creating virtual learning environments. Students engaged in simulation exercises via the SimLab website, allowing them to practice their skills and develop critical thinking and decision-making abilities in a safe, controlled environment [48]. Paired-samples t-tests compared pre- and post-test means across the five dimensions. This approach was appropriate given the within-subjects design, where each participant served as their own control. To address multiple comparisons, Holm–Bonferroni corrections were applied, and effect sizes (Cohen's dz) were reported alongside 95% confidence intervals to provide estimates of magnitude and precision. Analyses were conducted using SPSS (v.28) and crosschecked in Python (v.3.11) and R (v.4.5.1).

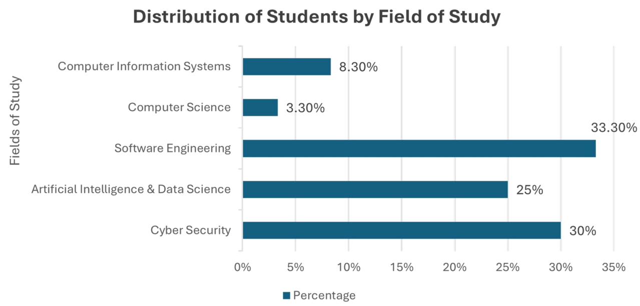


Fig. 1. Illustrates the fields of study of students interested in exploring the Metaverse.

Because a concurrent control group was not feasible in this implementation, we interpret findings as within-cohort associations. To reduce threats such as maturation and testing effects within a one-group pretest–posttest design, we added three control-free checks. These included (i) a specificity contrast showing that gains concentrate in workshop-targeted domains (Understanding, Tools) rather than less-targeted ones (Ethics, Challenges); (ii) permutation sign-flip tests (family-wise error controlled) to confirm non-random pre–post change; and (iii) regression-to-the-mean diagnostics using Oldham's method. Brief details will appear in Section III.E.

B. Procedure

This study was conducted after obtaining the approval of the authorities and the people concerned. It was approved by the university Deans' Council under Decision Number (2019-2018/15/19) and the Quality Assurance Council under Decision Number (2019-2018/20/06). Additionally, the research received approval from the Ministry of Higher Education and Scientific Research. Valuable support was provided by the College of Information Technology, the Deanship of Student Affairs, and the Career Guidance and Alumni Office. Students' consent was obtained during the distribution of questionnaires, and no personal information was collected. All responses were kept anonymous in accordance with data protection regulations. Immersive VR sessions followed rigorous safety protocols to minimize risk; participation was voluntary.

Some Metaverse tool workshops provided hands-on demonstrations to improve participants' understanding of the technology and equipment. Student involvement with advanced technologies was designed to enhance relevant academic and professional skills, providing practical experience and preparation for real-world challenges.

Pre-tests were conducted to determine baseline familiarity and perceptions; post-tests measured changes in knowledge, engagement levels, and usability.

C. Instrument

We designed a 37-item questionnaire organized into five dimensions: Understanding of the Metaverse (Q1–Q9), Familiarity with Tools (Q10–Q13), Perceived Academic Benefits (Q14–Q28), Awareness of Ethical Issues (Q29), and Reduction in Challenges (Q30–Q37). All items used a five-point Likert scale (1 = Strongly disagree, 5 = Strongly agree). Negatively keyed content was reverse-coded so that higher scores indicate more desirable outcomes; in particular, Q30 ("Did you face difficulties in using the Metaverse?") was recoded as $Q30_R = 6 - Q30$. Q29 is a single-item indicator of ethical awareness and, as such, is not eligible for internal-consistency reliability (α). Scoring followed a simple, transparent rule: each dimension score equals the mean of its keyed items, computed with pairwise handling of missing values and permitting no more than one missing response per subscale. The instrument mapping, anchors, keying rule, and scoring procedure are summarized in Table 2, and the associated reliability and validity evidence is presented in Tables 3–6.

Table 2. Instrument mapping

Construct	Items	Example stem (abbrev.)	Keying
Understanding of the Metaverse	Q1–Q9	"Metaverse term is clear…" (Q1)	All positive
Familiarity with Tools	Q10–Q13	"Familiar with Metaverse tools…" (Q10)	All positive
Perceived Academic Benefits	Q14–Q28	"Integrating Metaverse is beneficial…" (Q14)	All positive
Awareness of Ethical Issues	Q29	"Aware of ethical considerations…"	Single item
Reduction in Challenges	Q30–Q37	"Facilitates sustainability…" (Q33)	Q30 reversed; others positive

Table 3. Convergent validity (CR, AVE) by subscale (POST)

Factors	k	CR	AVE
F1_Understanding	9	0.864	0.435
F2_Tools	4	0.902	0.704
F3_Benefits	15	0.937	0.503
F5_Challenges	8	0.855	0.505

Note: Benchmarks: CR ≥ 0.70, AVE ≥ 0.50. F4 (Q29) is single item → CR/AVE = N/A.

Table 4. HTMT (Heterotrait–Monotrait), (item-level; POST)

Pair	HTMT
F1–F2	0.944
F1–F5	0.875
F3–F5	0.926
F2–F5	0.706

Note: Some pairs exceed common thresholds (0.90), again suggesting limited discriminant validity. Pairs involving F4 (single item) are N/A.

Table 5. Fornell–Larcker (diag = √AVE; off-diagonals = composite correlations, POST)

Factors	F1	F2	F3	F4	F5
F1	0.66	0.833	0.76	0.67	0.778
F2	0.833	0.839	0.649	0.644	0.567
F3	0.76	0.649	0.709	0.498	0.738
F4	0.67	0.644	0.498	1	0.416
F5	0.778	0.567	0.738	0.416	0.711

Note: Interpretation. Several off-diagonals exceed at least one √AVE → discriminant validity not fully satisfied (high interfactor overlap).

D. Validity and Reliability

- **Content Validity**: Six academic experts evaluated 37 items. Each item was rated for relevance, clarity, and essentiality. This process assessed content validity. Relevance was strong. I-CVI ranged from 0.83 to 1.00. S-CVI/Ave was 0.94. Several items reached full consensus (Q2–Q7). Some were borderline at 0.83 (Q1, Q9–Q11, Q13–Q16, Q23, Q24, Q26, Q28). Clarity showed the same pattern. I-CVI ranged from 0.83 to 1.00. S-CVI/Ave was 0.95. Many items had full agreement (Q1–Q7). A few were borderline at 0.83 (Q13, Q16, Q17, Q21, Q23, Q32–Q36). Essentiality was acceptable. Ratings used Essential, Useful, Not necessary. I-CVI ranged from 0.83 to 1.00. S-CVI/Ave was 0.83. With six experts, CVR ≥ 0.67 equals Ne ≥ 5. All 37 items met I-CVI ≥ 0.83 and CVR ≥ 0.67. Thirty-six items had Ne = 5; one item had Ne = 6. At the scale level, S-CVI/Ave was 0.91. This meets the 0.90 benchmark. The instrument is relevant, clear, and essentially adequate.
- **Construct Validity (Composite-based):** was evaluated with composite-based indicators because an ordinal Confirmatory Factor Analysis (CFA) (WLSMV) on post-test data did not converge (ceiling effects), so CFA results are not reported. Convergent validity met standards (CR ≥ 0.70; AVE ≥ 0.50; Table 3). Discriminant validity was mixed: HTMT flagged two pairs above the 0.90 cutoff (F1–F2 = 0.944; F3–F5 = 0.926) as shown in Table 4, while others were acceptable (F1–F5 = 0.875; F2–F5 = 0.706); F4 pairs are not applicable (single item). Fornell–Larcker likewise indicated overlap (e.g., $r_{F1–F2}$ = 0.833 > $\sqrt{AVE\_F1}$ = 0.66; Table 5), where $r_{F1–F2}$ is Pearson correlation coefficient between factor 1 (F1) and factor 2 (F2), and √AVE is Average Variance Extracted. Internal consistency was acceptable to excellent (Cronbach's α post = 0.707–0.935; pre = 0.797–0.945;

Table 6); Q30 was reverse-scored, and the single-item ethics indicator (Q29) is not eligible for α.

- **Internal Consistency Reliability:** It was assessed using Cronbach's α for each multi-item subscale at pre-test and post-test. Following common guidelines, values of $\alpha \geq 0.70$ were considered acceptable for research use. The negatively keyed item Q30 ("Did you face difficulties in using the Metaverse?") was reverse-scored prior to forming composites and computing α ($Q30_R = 6 - Q30$) so that higher scores uniformly indicate improvement. The Ethics indicator (Q29) is a single item and therefore not eligible for α. Results are summarized in Table 6.

Table 6. Cronbach's α by subscale at pre-test and post-test.

Dimension	Item	Cronbach's α (Pre-test)	Cronbach's α (Post-test)
Understanding of Metaverse	Q1–Q9	0.896	0.866
Familiarity with Tools	Q10–Q13	0.797	0.894
Perceived Academic Benefits	Q14–Q28	0.945	0.935
Reduction in Challenges	Q30–Q37	0.886	0.707

Overall, the instrument shows strong content validity (expert I-CVI = 0.83–1.00; scale S-CVI/Ave ≥ 0.90; CVR met) and acceptable-to-excellent reliability ($\alpha = 0.707$–0.945). Convergent validity is adequate for F2, F3, F5 (CR ≥ 0.70; AVE ≥ 0.50) but marginal for F1 (CR = 0.864; AVE = 0.435). We retained F1 given its high CR and strong content validity, noting that AVE can be modest when items capture a broad facet. Discriminant validity is mixed (HTMT > 0.90 for F1–F2 and F3–F5; several Fornell–Larcker violations), consistent with theoretical proximity among these constructs. Therefore, we interpret inter-construct differences cautiously while focusing on the reliable composite scores.

E. Statistical Analysis

We analyzed paired pre–post responses for the five primary dimensions ($n = 60$; $df = 59$) using two-tailed paired t-tests with $\alpha = 0.05$. To control multiplicity across the five tests, we applied the Holm–Bonferroni step-down procedure. All analyses used keyed scores (negatively worded items reverse-coded; $Q30_R = 6 - Q30$). Analyses were conducted in SPSS (v 28.0.1) and crosschecked in Python (v 3.11); p-values are reported in threshold format (e.g., $p < 0.001$).

- **Confidence intervals:** A 95% confidence interval (CI), as shown in Eq. (1), provides a plausible range for the true mean change (post − pre) in the population, quantifying both effect magnitude and sampling uncertainty. Unlike a p-value (which only tests whether any effect exists), the CI shows the size and direction of the effect and the estimate's precision (narrow = more precise, wide = less precise). If the CI for the mean difference does not include 0, the improvement is statistically significant.

$$\overline{d} \pm t_{.975,df} \times SE \quad (1)$$

where $\overline{d}$ = mean paired difference (post − pre); $t_{.975,\,df}$ = t-critical value for a two-tailed 95% CI with $df = n - 1 = 59$, $SE = \frac{s_d}{\sqrt{n}}$ is the standard error of $\overline{d}$; s_d = SD of paired differences; $n = 60$.

- **Effect sizes (paired):** Effect sizes, as shown in Eq. (2), quantify the magnitude of the pre–post change in units comparable across measures and studies, complementing p-values (which are sensitive to sample size). For paired designs, we use Cohen's d_z—a within-subject effect size that standardizes the mean change by the variability of individual changes:

$$d_z = \frac{t}{\sqrt{n}} = \frac{\overline{d}}{s_d} \quad (2)$$

We report d_z with small-sample correction, where d_z = Cohen's paired effect size; t = paired t-statistic; $n = 60$; $\overline{d}$ = mean paired difference; s_d = SD of paired differences.

- **Small-sample correction:** To mitigate slight positive bias of standardized mean-change estimates for modest samples, we report Hedges' small-sample–corrected effect size as shown in Eq. (3).

$$g_z = J d_z, J \approx 1 - \frac{3}{4\,df - 1} (\approx 0.987 \; for \; df = 59) \quad (3)$$

where g_z = Hedges' small-sample-corrected effect size and J is the correction factor (≈ 0.987 for $df = 59$).

- **Reverse-coding:** where $Q30_R$ denotes the keyed value used in composites and reliability, as shown in Eq. (4).

$$Q30_R = 6 - Q30 \quad (4)$$

- **Robustness check:** We conducted a Wilcoxon signed-rank test on paired differences as a nonparametric sensitivity check. Results are reported alongside paired t-tests to assess concordance. The Wilcoxon tests confirmed significant median gains across all dimensions (e.g., Understanding: $W = 124.5$, two-sided $p = 1.51 \times 10^{-8}$, $n = 60$ paired observations), consistent with the parametric t-tests.
- **Additional internal-validity checks:** We compared the average change in targeted domains (F1, F2) with less-targeted domains (F4, F5) to form a domain-specificity contrast. We conducted sign-flip permutation tests (10,000 flips; max-T) to obtain family-wise error-controlled p-values for pre–post changes. Then, we reported Oldham's correlation between the within-person average and the change to assess regression-to-the-mean. All checks were computed on the paired cohort ($n = 60$) using the instrument's scoring rule (≤1 missing item per subscale at pre and post).

IV. Statistical Analysis of Educational Improvements

The statistical analysis conducted in this study shows very important improvements on many dimensions of education, where the p-values are less than 0.05, meaning the changes are highly unlikely to be the result of random variation. This paper reports the results and explains their implications for integrating Metaverse and VR technologies into undergraduate education. It shows in detail the statistical methodology used, results obtained, and implications of such findings. The focus will be on major aspects related to the improvement of students' knowledge of the Metaverse, familiarity with digital tools, perceived academic benefits, ethical awareness, and the diminution of challenges in using these technologies.

A. Statistical Approach

The effectiveness of the Metaverse-based learning interventions was tested using a pre-test/post-test design, comparing students before and after exposure to the Metaverse tools. Paired comparison allowed for the assessment of individual changes over time, which in turn enabled the attribution of observed differences directly to the intervention. This approach was appropriate for the measurement of the impact of the Metaverse on key educational outcomes.

B. Test Metrics

The effect of the Metaverse intervention was measured on the following five dimensions, which are further elaborated below, as exemplified in Table A1, which show sample questions on each category:

- **Understanding of the Metaverse**: The ability of the learners to understand the concepts of the Metaverse and its uses in teaching and learning.
- **Familiarity with Tools**: The extent to which students became familiar with the digital tools and technologies used in the Metaverse environment.
- **Perceived Academic Benefits**: Students' perceptions of how the Metaverse-based learning experience has affected their academic development in knowledge retention and enhancement of skills.
- **Awareness of Ethical Issues**: The level of awareness among the students in using immersive technologies regarding ethical concerns, such as data privacy concern and responsible digital citizenship.
- **Reduction in Challenges**: Obstacles or difficulties that might have been experienced by the student while engaging in the Metaverse tools, including technological problems, challenges related to usability, and physical discomfort.

C. Descriptive Analysis

The participants' responses for each dimension are presented in Fig. 2. The comparative analysis between pre-test and post-test responses highlights notable shifts in participants' perceptions across the five dimensions: (a) Understanding of the Metaverse, (b) Familiarity with Tools, (c) Perceived Academic Benefits, (d) Awareness of Ethical Issues, and (e) Reduction in Challenges, as shown in Fig. 2.

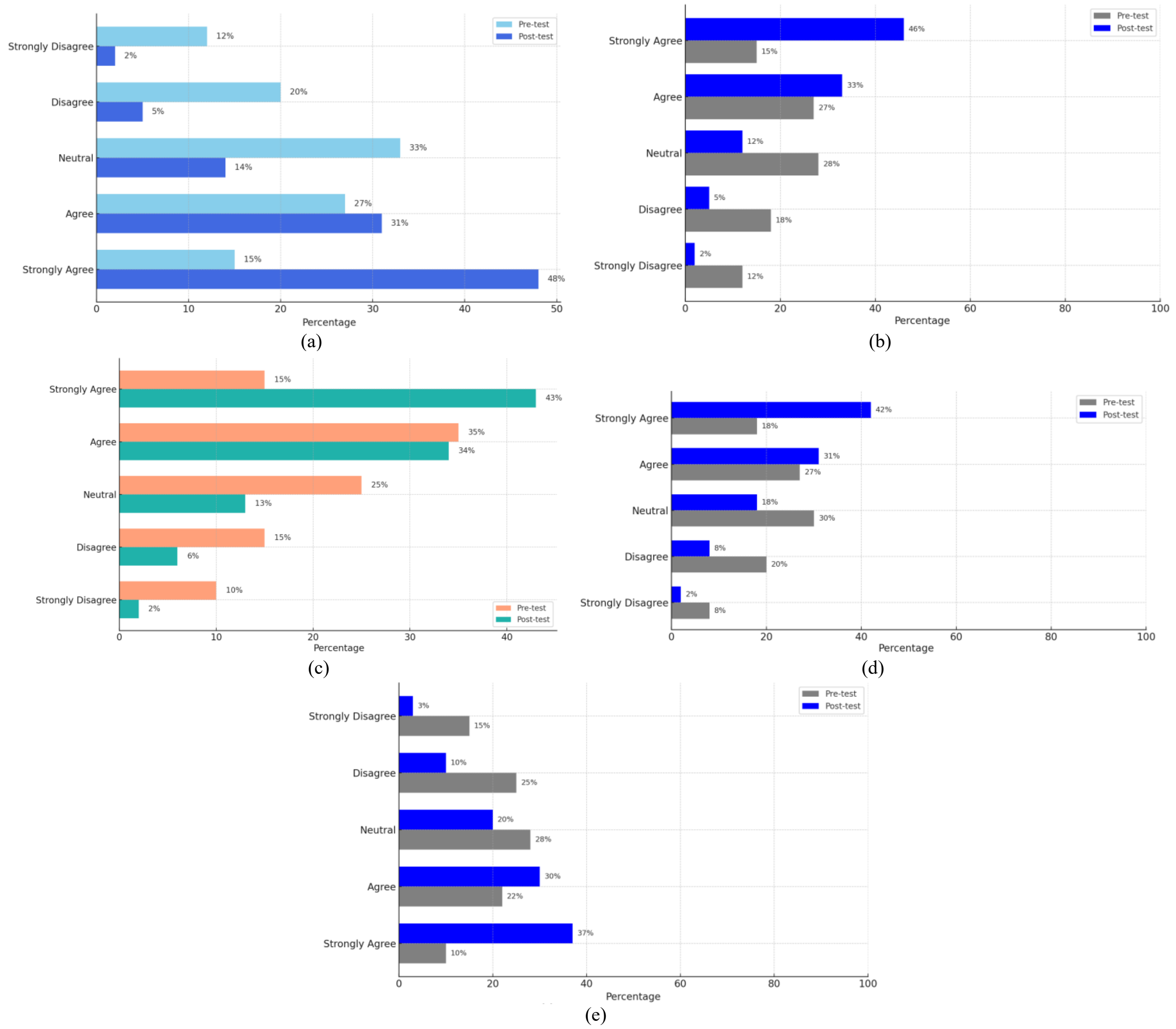


Fig. 2. Pre- and post-test response distributions across five dimensions: (a) understanding of Metaverse concepts, (b) familiarity with tools, (c) perceived academic benefits, (d) awareness of ethical issues, and (e) reduction in challenges. Responses were measured on a 5-point Likert scale (1 = Strongly disagree to 5 = Strongly agree). Variability for all panels is shown in Fig. 3. Pre-test and post-test are distinguished by the legend colors in each panel.

A substantial increase in Strongly Agree responses is evident across all categories in the post-test, particularly in Understanding of the Metaverse. This significant rise in agreement levels indicates enhanced conceptual clarity following the intervention. Similarly, participants demonstrated increased familiarity and confidence with tools, as reflected by a significant rise in Agree and Strongly Agree responses in the corresponding category. In terms of Perceived Academic Benefits, participants demonstrated a clear shift toward recognizing the Metaverse academic value. The data reflects fewer Neutral, Disagree, and Strongly Disagree responses in the post-test across all dimensions, indicating that uncertainty diminished while positive perceptions increased. Especially notable is the trend in the Reduction in Challenges category, where participants expressed greater agreement, suggesting that participants found the learning experience more manageable post-intervention. Collectively, the instructional program appears effective in enhancing both confidence and positive attitudes toward the use of the Metaverse in academic contexts.

D. *Statistical Test*

A paired t-test was applied to compare the pre-test and post-test mean scores for each of the five dimensions. This test was chosen because it is effective in determining whether there are significant differences in scores from the same group of participants, before and after the intervention. A paired t-test ensures that the differences observed are not due to variability between separate groups but rather reflect changes within the same group over time.

E. *Significance Level (α)*

The threshold for statistical significance was set at 0.05 ($\alpha = 0.05$), which means that there is less than a 5% probability that the observed differences are due to random variation. If the *p*-value is less than 0.05, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted, indicating a significant effect of the Metaverse-based learning intervention on the measured outcomes.

F. *Results of Statistical Analysis*

1) *Improvements across dimensions*

The pre-test responses were analyzed to identify the baseline knowledge and perceptions of students about the Metaverse, as presented in Table 7.

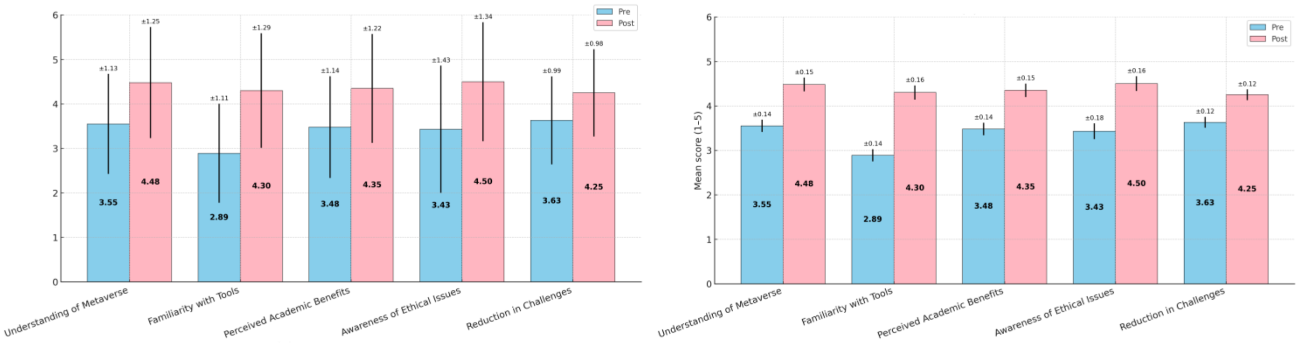
Table 7. Pre-test dimensions and their interpretations

Dimension	Items	Interpretation
Understanding of Metaverse Concepts	Q1–Q9	Moderate familiarity with the term
Familiarity with Tools and Applications	Q10–Q13	Limited knowledge of tools and platforms
Perceived Academic Benefits	Q14–Q28	Positive expectations for learning
Awareness of Ethical Considerations	Q29	Neutral stance on ethical aspects
Reduction in Challenges	Q30–Q37	Moderate difficulties reported

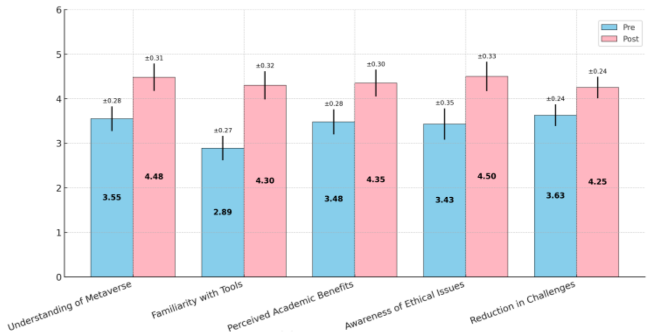
The evaluation of dimensions in the pre-test along with their respective scores provides the following key insights:

- **Moderate Understanding**: Based on their responses, students displayed a basic understanding of the Metaverse. Their grasp of real-world applications and the underlying technologies appears to be superficial.
- **Optimism for Educational Impact:** The integration of the Metaverse into educational settings appears poised to enhance the learning experience significantly. By offering immersive environments, it enables students to participate actively, moving beyond traditional, often passive classroom methods. This shift not only increases engagement but also broadens the range of activities available, potentially transforming educational practices in meaningful ways.
- **Challenges in Usability**: The findings indicate that students are struggling with Metaverse technologies; many appear unsure of how to navigate or utilize these virtual environments without guidance. Consequently, there is a need for additional support and targeted training sessions to ensure effective engagement.

Fig. 3 illustrates a comparative analysis of pre-test and post-test mean scores across five key educational dimensions. Notable improvements were observed in students' understanding of the Metaverse (from 3.55 to 4.48), familiarity with tools (2.89 to 4.30), perceived academic benefits (3.48 to 4.35), and awareness of ethical issues (3.43 to 4.50). Similarly, the mean score for reduction in challenges increased from (3.63 to 4.25), indicating a reduction in perceived barriers. These findings suggest that the intervention had a significant positive impact on student engagement, skill development, and technological confidence.



(a) (b)



(c)

Fig. 3. Comparison of error metrics for pre- and post-test mean scores across five dimensions. Blue bars represent pre-test scores, pink bars represent post-test scores. The vertical axis shows the 1–5 Likert scale (fixed to 0–6 for clarity). Error bars represent (a) mean ± standard deviation, (b) mean ± standard error, and (c) mean ± 95% confidence intervals.

The results are statistically strong and robust, with consistent gains and narrow confidence intervals confirming the reliability of the findings. Error bars are presented to enhance interpretation: The Standard Deviation (SD) in Fig. 3(a) illustrates variability among individual responses, the Standard Error (SE) in Fig. 3(b) reflects the precision of the sample mean, and the 95% Confidence Interval (CI) in Fig. 3(c) highlights the accuracy of the estimated mean values. Mean values are displayed inside the bars for clarity, and the scale was fixed at 0–6 to align with the 5-point Likert instrument. Collectively, these visualizations clearly indicate both the variability within the data and the precision of the observed improvements.

Results of the paired t-test show that improvements in all measured dimensions are significant. The main results of the statistical analysis are summarized in Table 8.

Table 8. Results of paired t-test across dimensions

Dimension	Items	Pre-Test Mean	Post-Test Mean	Mean Difference	*t*-Statistic	*p*-Value
Understanding of Metaverse	Q1-Q9	3.55	4.48	0.93	18.5	< 0.001
Familiarity with Tools	Q10-Q13	2.89	4.30	1.41	28.05	< 0.001
Perceived Academic Benefits	Q14-Q28	3.48	4.35	0.87	17.31	< 0.001
Awareness of Ethical Issues	Q29	3.43	4.50	1.07	21.29	< 0.001
Reduction in Challenges	Q30-Q37	3.63	4.25	0.62	12.33	<0.001

As shown in Table 9, all five dimensions show clear, precise pre–post gains: every 95% CI is strictly positive and narrow. In addition, we controlled multiplicity across the five tests using Holm–Bonferroni; Table 9 shows Holm-adjusted p-values. All values are < 0.001, ruling out chance as an explanation. The largest improvement is in Familiarity with Tools (CI [1.31, 1.51], $d_z = 3.62$), indicating an exceptionally strong, practical increase in students' proficiency with platforms and tools. Substantial effects also appear for Awareness of Ethical Issues (d_z = 2.75, CI [0.97, 1.17]), Understanding of the Metaverse (d_z = 2.39, CI [0.83, 1.03]), and Perceived Academic Benefits (d_z = 2.23, CI [0.77, 0.97]). Reduction in Challenges remains meaningfully improved (d_z = 1.59, CI [0.52, 0.72]) even after reverse coding the negatively keyed item (Q30), showing that perceived obstacles decreased.

Table 9. Pre–post improvements with 95% CIs and effect sizes

Dimension	95% CI for Difference	*p*-value (Holm-adjusted)	Cohen's dz
Understanding of Metaverse	[0.83, 1.03]	< 0.001	2.39
Familiarity with Tools	[1.31, 1.51]	< 0.001	3.62
Perceived Academic Benefits	[0.77, 0.97]	< 0.001	2.23
Awareness of Ethical Issues	[0.97, 1.17]	< 0.001	2.75
Reduction in Challenges	[0.52, 0.72]	< 0.001	1.59

Taken together, the uniformly large effect sizes and tight confidence intervals indicate a strong educational impact of the intervention across knowledge, ethics, perceived benefits, and day-to-day usability. To probe whether gains reflected workshop-targeted content rather than a uniform re-test effect, we contrasted the average change in targeted domains (F1 Understanding, F2 Tools) with less-targeted domains (F4 Ethics, F5 Challenges). The difference in change was 0.35 (95% CI 0.18–0.52, p = 0.00014; n = 60), consistent with the contrast implied by the Table 9 confidence-interval midpoints. A permutation sign-flip test (max-T, family-wise error controlled) corroborated that pre–post gains were non-random (FWER-adjusted p < 0.0001), and regression-to-the-mean diagnostics showed a small negative Oldham correlation (r = − 0.42) on the same cohort. We therefore report within-cohort associations consistent with benefit.

Using a distribution-free check, Table 10 (Wilcoxon signed-rank, n = 60) confirms significant median improvements on all five dimensions, with extremely small p-values (Understanding of the Metaverse: W = 124.5, $p = 1.51\times10^{-8}$; Familiarity with Tools: W = 92.5, $p = 3.23\times10^{-9}$; Perceived Academic Benefits: W = 202.5, $p = 1.56\times10^{-7}$; Awareness of Ethical Issues: W = 146, $p = 4.14\times10^{-6}$; Reduction in Challenges: W = 207.5, $p = 5.09\times10^{-7}$). These results corroborate the paired t-tests and indicate that the gains are not an artifact of normality assumptions or outliers; even under Holm–Bonferroni across five tests, all would maintain a value of p < 0.001.

Complementing significance with magnitude, Table 11 (effect sizes) shows very large paired effects in four domains and a large effect for Reduction in Challenges: Familiarity with Tools is exceptional (Cohen's d_n = 3.621; Hedges' g_n = 3.575), followed by Awareness of Ethical Issues (d_n = 2.749; g_n = 2.713), Understanding of the Metaverse (d_n = 2.388; g_n =

2.358), and Perceived Academic Benefits (d_n = 2.235; g_n = 2.206). Reduction in Challenges demonstrates a strong and meaningful improvement (d_n = 1.592; g_n = 1.571). The slight decrease from d_n to Hedges' g_n (~1–1.5%) reflects the standard small-sample correction (df = 59) and does not affect the overall interpretation. Taken together, the consistency of robust significance and very large effect sizes provides strong evidence of the intervention's substantial educational impact, spanning knowledge acquisition, tool proficiency, perceived benefits, ethical awareness, and practical usability.

Table 10. Wilcoxon signed-rank results with N paired = 60

Dimension	Wilcoxon W	*p*-value
Understanding of Metaverse	124.5	1.51×10^{-8}
Familiarity with Tools	92.5	3.23×10^{-9}
Perceived Academic Benefits	202.5	1.56×10^{-7}
Awareness of Ethical Issues	146	4.14×10^{-6}
Reduction in Challenges	207.5	5.09×10^{-7}

Table 11. Effect sizes of Cohen's dz vs Hedges'gz

Dimension	Cohen's dz	Hedges'gz
Understanding of Metaverse	2.388	2.358
Familiarity with Tools	3.621	3.575
Perceived Academic Benefits	2.235	2.206
Awareness of Ethical Issues	2.749	2.713
Reduction in Challenges	1.592	1.571

G. Interpretation of Results

The statistical analysis shows significant improvements in the following dimensions:

- **Understanding of the Metaverse**: The pre-test means of 3.55 increased to 4.48 in the post-test with a mean difference of +0.93 and t-statistic of 18.5 ($p < 0.001$), which means there was a significant improvement in knowledge of the Metaverse by students.
- **Familiarity with Tools**: The increase in Metaverse tool familiarity among the students was intensive. The pre-test mean was 2.89, and the post-test mean was 4.30, with a mean difference of +1.41 and a t-statistic of 28.05 ($p < 0.001$), which verifies that the intervention significantly improved the level of perceived comfort and competence of students regarding the digital tools associated with the Metaverse.
- **Perceived Academic Benefits**: The perceived academic benefits improved dramatically, with its pre-test mean of 3.48 increasing to 4.35 in the post-test. The mean difference of +0.87, together with a t-statistic of 17.31 ($p < 0.001$), is indicative that Metaverse intervention had a positive effect on the academic perceptions of students in relation to their engagement and motivation to learn.
- **Awareness of Ethical Issues**: This dimension showed a statistically significant gain in ethical awareness: from a pre-test mean of 3.43 to a post-test mean score of 4.50, with a mean difference of +1.07 and a t-statistic of 21.29 ($p < 0.001$). This indicates that the intervention was effective in addressing ethical considerations related to immersive technology use.
- **Reduction in Challenges:** The intervention also showed a reduction in the challenges faced by students in using Metaverse tools. The mean score for challenges was 3.63 at pre-test and had increased to 4.25 at post-test with a mean difference of +0.62 and t-statistic of 12.33 at $p < 0.001$. This demonstrates that the intervention was effective at reducing usability problems and generally enhancing the experience of using Metaverse technologies among students.

H. Interpretation of Significant Improvements for Education

1) Educational significance

The following improvements in each respective dimension have significant implications for education:

- **Enhanced Understanding and Familiarity**: Immersive technologies have been found to be effective pedagogical tools that can increase learners' knowledge about the Metaverse and familiarize them with digital tools. Hakeem *et al.* [23] demonstrated how the integration of 3D holography and gesture interaction encourages active learning and improves students' knowledge and technical skills. These findings are consistent with those by Mazhar and Rifaee [12], who illustrated the educational value of virtual reality in creating a highly interactive and engaging learning space. This complements previous research findings showing that immersive technologies contribute significantly in enhancing active learning and knowledge acquisition [8, 9].
- **Increased Perceived Academic Benefits**: Numerous studies confirm significant academic benefits that occur when education uses immersive tools like VR and the Metaverse. When students engage with these interactive environments, their intrinsic motivation and level of engagement tend to increase, which leads to better learning outcomes. As concluded by Mazhar and Rifaee [12], learners generally prefer immersive and interactive learning experiences over traditional methods. This positive perception suggests that integration could enhance academic performance. It also supports adopting more Metaverse-based interventions in future teaching practice.
- **Ethical Awareness**: Immersive technologies are increasingly used in education, so curricula needs to include ethical considerations. As Hakeem *et al.* [23] asserted any move toward these technologies must prioritize accessibility and inclusion, raising the critical point of ensuring equity in virtual environments. Durak *et al.* [25] noted resource imbalances and a persistent digital divide. Shedding light on these issues is critical to fostering learners' ethical awareness. With greater adoption of immersive tools, it becomes essential for students to develop a nuanced understanding of ethical challenges, including privacy concerns and the principles of responsible digital citizenship, to be able to operate in such environments both effectively and responsibly.

2) Addressing usability challenges

This study found that usability issues have decreased. This outcome points to the workshops' effectiveness, as participants seemed better equipped to navigate the technology and overcome earlier difficulties. This suggests that formal training and hands-on workshops helped reduce early adoption barriers. The point highlighted here calls for focused interventions in building confidence and competence among students with new tools and technologies. It is also important to address concerns related to issues of accessibility, equipment, and health problems, such as motion sickness, for maximal effects in interventions based on the Metaverse [22].

I. Limitations and Considerations

While the results are encouraging, there are some limitations to consider:

- **Threats to Validity:** Without a concurrent control group, causal inference was limited. However, gains were larger in workshop-targeted domains, remained significant under permutation-based inference, and showed a small negative Oldham correlation. Together, these factors reduced the likelihood that results were solely due to maturation, testing, or regression-to-the-mean. Accordingly, we framed the findings as associations within one cohort. This limitation means that while improvements are clearly observed, the degree to which they can be attributed exclusively to the intervention should be interpreted with caution.
- **Sample Size**: This study was conducted with a sample of 60 undergraduate students, which slightly limits the generalizability of the findings to larger or more diverse populations. Further studies with larger sample sizes from various age groups are needed to validate the results across different educational levels. Consequently, interpretations of the current results should be restricted to cohorts of similar size and background, and broader claims should await replication with larger samples.
- **Discipline-Specific Outcomes**: This study targeted IT students to evaluate the effectiveness of a structured intervention designed to enhance their understanding and competency regarding the Metaverse. As the findings are based solely on this specific discipline, the results may not be generalizable to students in other fields. To strengthen external validity and explore the intervention's impact more broadly, future studies should examine similar structured approaches in diverse academic disciplines such as humanities, education, or social sciences. Therefore, current interpretations should be viewed as discipline-specific, and caution is advised when extrapolating these findings beyond IT students.
- **Short-Term Scope**: This study examined only the immediate impact of the Metaverse intervention and did not include long-term outcomes. Further research is thus required to examine the long-term impact of immersive technologies on student learning and career development. As such, interpretations of the present findings should be limited to short-term gains, with the understanding that long-term sustainability of these effects remains to be tested.

J. Research Implications

This study extends the literature on immersive learning and highlights the Metaverse's role in strengthening constructivist and experiential frameworks. The findings confirm that immersive technologies can effectively enhance student understanding, engagement, and academic benefits, thus contributing to broader theories of digital and technology-enhanced education.

From a practical perspective, the results suggest that Metaverse-based interventions can be applied by instructors and curriculum designers to enrich teaching strategies, reduce challenges, and increase student readiness for technology-driven careers. At the policy level, universities and decision-makers may leverage these insights to promote inclusive, innovative, and future-oriented learning environments.

V. Discussion

This study investigated the effects of a structured Metaverse-based intervention on undergraduate IT students in a Middle Eastern university. The discussion is organized around the three research questions and highlights how the findings address each one.

Research Q1: To what extent does the structured instructional intervention enhance IT students' conceptual understanding of the Metaverse?

The results showed a significant improvement in students' conceptual understanding, with mean scores increasing from 3.55 to 4.48. This gain suggests that structured exposure to immersive technologies can build a clearer and more comprehensive grasp of Metaverse concepts. Similar outcomes have been reported in prior studies where VR-based interventions improved learners' conceptual knowledge and critical reasoning [20, 30, 31]. In this cohort, the clear improvement supports the argument that the Metaverse can serve not only as a tool for visualization but also as a medium for fostering deeper academic comprehension.

Research Q2: Does the intervention significantly improve students' familiarity with Metaverse-related tools, their perceived academic benefits, and awareness of associated ethical considerations?

The intervention yielded strong improvements in familiarity with tools ($M = 2.89 \rightarrow 4.30$) and awareness of ethical issues ($M = 3.43 \rightarrow 4.50$), confirming the intervention's dual impact on technical and ethical dimensions of learning. These findings are consistent with studies showing that immersive technologies promote both digital literacy and awareness of responsible technology use [4, 17–19]. Improvements in perceived academic benefits ($M = 3.48 \rightarrow 4.35$) also highlight those students increasingly recognized the relevance of the Metaverse to their academic and professional development. Collectively, the findings indicate two primary effects: enhanced skills and more positive attitudes toward adopting technology in education.

Research Q3: Does the intervention lead to a measurable reduction in the challenges and barriers faced by students when engaging with Metaverse technologies in an academic environment?

The reduction in challenges ($M = 3.63 \rightarrow 4.25$) demonstrates that the intervention was successful in lowering barriers related to usability, accessibility, and confidence. This finding reflects a broader theme in the literature: guided immersion can mitigate initial difficulties students face when working with emerging technologies [6–8]. In this case, the structured approach, which emphasized both practice and reflection, appears to have supported students in overcoming concerns about complexity or unfamiliarity.

Taken together, these findings provide empirical support for integrating Metaverse-based activities into IT curricula in higher education. The study not only confirms measurable improvements across multiple dimensions but also responds to the lack of empirical evidence from the Middle East, a region still in the early stages of immersive technology adoption. By combining technical, ethical, and pedagogical perspectives, the intervention offers a replicable instructional model that may guide future research and curriculum design.

VI. Conclusion

In the single-institution IT sample of this paper, the integration of Metaverse technologies led to clear improvements in students' perceptions, skills, and ethical awareness. Beyond the measurable statistical gains, the study suggests, within this context, how immersive platforms can enhance student engagement, build familiarity with emerging tools, and reduce concerns related to usability and accessibility.

This study examined how Metaverse integration affects perceptions and competency development in undergraduate IT students at a Middle Eastern university. The use of immersive tools there is still at an early stage. The results suggest the feasibility and value of introducing such technologies at the studied institution, which may extend to similar settings with limited prior infrastructure or experience. This research highlights the potential for similar IT programs in the Middle East to leverage Metaverse tools as part of broader digital transformation efforts. It also emphasizes the importance of early exposure to immersive environments in preparing IT students for the evolving digital economy.

Furthermore, this study makes an important contribution by addressing several identified research gaps in the current literature. First, it provides empirical evidence from a region, specifically the Middle East, where immersive educational technologies are still in the early stages of adoption, thereby contributing to a more geographically inclusive body of knowledge. Second, the intervention improved technical competencies and ethical awareness in this cohort. This offers initial evidence that immersive technologies can enhance critical thinking and responsible use. Third, the study offers a replicable model for integrating Metaverse tools into undergraduate IT curricula. It can be adapted and tested in other contexts, answering calls for structured strategies for immersive environments.

However, several limitations remain, pointing to important directions for future research. The study did not assess scalability across different institutions, nor did it investigate infrastructural or faculty-related challenges associated with broader implementation. Moreover, the long-term effects of Metaverse integration on knowledge retention, professional readiness, and inclusive accessibility were beyond the scope of this work. Subsequent research should address implementation challenges related to scalability, affordability, teacher preparation, and long-term integration. Additionally, later investigations could examine sustained impacts over time and assess how immersive technologies influence learning retention, professional readiness, and equity in access to advanced educational experiences, particularly in under-resourced environments.

Appendix: Questionnaire

Table A1. Questionnaire dimensions and item mapping (Q1–Q37): (a) Understanding of the Metaverse (Q1–Q9), (b) Familiarity with tools (Q10–Q13), (c) Perceived academic benefits (Q14–Q28), (d) Awareness of ethical issues (Q29), and (e) Reduction in challenges (Q30–Q37)

Items	No.	Question Text
Understanding of the Metaverse	1	Does the term 'Metaverse' seem clear and well understood?
	2	Are you aware of various Metaverse applications?
	3	Do you understand the advantages and disadvantages of the Metaverse?
	4	Do you believe the Metaverse will play a significant role in the future of technology?
	5	Do you see opportunities to expand the use of the Metaverse beyond the traditional academic context?
	6	Does the Metaverse provide a responsive learning experience tailored to the needs of students from diverse cultural backgrounds?
	7	Does the Metaverse's cultural diversity enrich the learning environment at the university?
	8	Does the Metaverse meet your academic expectations and needs overall?
	9	Are you satisfied with your experience using the Metaverse?
Familiarity with Tools	10	Are you familiar with the tools and platforms used in Metaverse development?
	11	Do you have knowledge of various tools used to design and review experiences in the Metaverse?
	12	Are you aware of SimLab and its role in Metaverse design?
	13	Does the Metaverse make accessing educational content easier compared to traditional methods?
Perceived Academic Benefits	14	Do you believe integrating Metaverse concepts into the IT curriculum is beneficial?
	15	Do you understand the impact of the Metaverse on user interaction and experiences?
	16	Does the Metaverse help you understand study materials?
	17	Does the Metaverse enhance your interaction with study materials better than traditional methods?
	18	Does the Metaverse contribute to achieving better results in exams and assignments?
	19	Does the Metaverse enhance interaction between students and professors during lessons?
	20	Do you benefit from the availability of educational resources via the Metaverse to enhance your understanding of study topics?
	21	Does the Metaverse help you prepare for exams effectively?
	22	Have you benefited from using the Metaverse in reviewing materials and understanding basic concepts?
	23	Does the Metaverse facilitate the formation of effective study groups among students?
	24	Do you prefer using the Metaverse in the learning process?
	25	Does using the Metaverse contribute to developing your research and analytical skills?
	26	Does the Metaverse help improve your balance between academic and personal life?
	27	Does the Metaverse enhance social interaction with classmates at university?
	28	Does the Metaverse encourage collaboration and exchange of ideas among students?
Awareness of Ethical Issues	29	Are you aware of the ethical considerations associated with the Metaverse?
Reduction in Challenges	30	Did you face difficulties in using the Metaverse?
	31	Can the integration of the Metaverse with traditional teaching methods be improved in the future?
	32	Does the Metaverse provide opportunities to develop skills necessary for the job market?
	33	Can the Metaverse be a contributing factor to achieving sustainability in education?

34	Do you believe there is a need to enhance communication between students and the university administration regarding the use of the Metaverse?
35	Does the Metaverse encourage personal motivation to explore more?
36	Does the Metaverse enhance self-efficacy and continuous learning among students?
37	Does the Metaverse contribute to enhancing digital transformation in the educational process?

Note: Items use a 5-point Likert scale; negatively keyed items are reverse-coded prior to aggregation

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Manar Mizher: Conceived the study, acquired funding, supervised the work, designed the methodology, conducted the statistical analysis, and wrote, reviewed, and edited the manuscript. Manal Mizher: Developed methodology, curated data, and created visualizations. Ayman Abdalla: Conducted the investigation, wrote sections, and reviewed and edited the manuscript. Mo'en Alnasraween: Designed the questionnaire and performed validation. Ahmad Mazhar: Developed software, curated data, and produced visualizations. Aman Altamimi: Developed software and conducted statistical analysis. All authors approved the final version.

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