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DISSECTION OF FUTURE: STUDENT PERCEPTIONS OF METAVERSE-BASED ANATOMY EDUCATION- A CROSS-SECTIONAL STUDY

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ABSTRACT

Anatomy education remains a foundation of the medical curriculum, with cadaveric dissection offering invaluable hands-on learning. Yet, limitations in conveying complex structures and restricted clinical exposure in early years highlight the need for innovative approaches. With rapid technological progress, medical education increasingly integrates immersive tools such as the metaverse to enhance anatomical understanding beyond traditional cadaveric dissection. This study evaluated undergraduate medical students' perceptions of metaverse-assisted anatomy learning. A cross-sectional survey among 275 medical students at RAKMHSU

assessed perceptions across five themes after exposure to metaverse-based anatomy sessions. A standardized questionnaire, aligned with UTAUT-2 constructs, was used for evaluation. No significant gender differences were observed in prior digital experience or comfort with technology. Although 15.1% of females and 21.4% of males reported extensive experience, most showed moderate exposure. Year-wise trends indicated increasing proficiency, but without statistical significance. UTAUT-2 analysis showed males scored higher in three constructs, i.e., Effort Expectancy (14.75 ± 2.96 vs. 14.02 ± 2.68; p = .042), Social Influence (7.41 ± 1.68 vs. 6.92 ± 1.62; p = .019), and Habit (14.22 ± 3.28 vs. 13.04 ± 3.39; p = .005). Performance Expectancy remained uniformly high across groups. Students demonstrated overall readiness for metaverse integration, with fourth-years showing the highest acceptance. A dip in third-year enthusiasm may reflect transitional academic demands. Metaverse-based anatomy learning was well-received, with high performance expectancy and strong behavioral intention across genders. Minor variations in effort expectancy, social influence, and habit suggest targeted support may further enhance adoption.

KEYWORDS: Metaverse; Anatomy Education; UTAUT-2; Medical Students; Technology Acceptance; Digital Learning.

1. INTRODUCTION

Medicine is an ever-changing landscape, forced to continuously evolve in response to all challenges that come with constant advancements in the pursuit of better patient care. This has paved the way for implementing novel techniques, such as minimally invasive surgery and robotic surgery, minimizing complications, reducing hospital stays, and improving patient outcomes. [1]

Anatomy education is one of the cornerstones of medical curriculum worldwide, providing essential preclinical knowledge for future practitioners. A solid grasp of anatomy underpins clinical skills such as physical examination, symptom interpretation, and surgical practice [2–4]. Cadaveric dissection has traditionally been central to anatomy teaching, offering unique insights into large organ structures, three-dimensional relationships, and anatomical variations [5–7]. Proponents highlight its unmatched value in hands-on learning [8, 9].

However, it has limitations in conveying complex concepts like surface anatomy and small or intricate structures, including nerves and vessels [5]. Additionally, some students experience stress and anxiety in the dissection environment [10–12].

Clinical teaching is often limited to instructor-led demonstrations and observations due to time, ethical, and regulatory constraints, making it difficult to connect theory with practice [13]. Clinical simulations have been shown to enhance technical skills, motivation, and the learning environment [14]. The metaverse, built on technologies like virtual, augmented, and mixed reality, offers immersive, multisensory simulations that support experiential learning [15].

First introduced in the 1992 novel Snow Crash, the metaverse is a digital copy of the real world, used across domains such as gaming, social networking, and training. It bridges physical and virtual spaces using interactive tools like VR headsets and smart glasses [16]. In higher education, the metaverse can create engaging, interactive learning experiences, allowing students to explore virtual environments that support deeper understanding [17].

This technology has the potential to transform education by fostering collaboration, communication, and improved learning outcomes [18]. The modern metaverse is depicted through a computer-generated environment. In this immersive and interconnected virtual world, users engage various senses, including sight, hearing, kinesthesia, and proprioception, to interact with others. Although definitions may vary, multisensory input generally allows users to feel integrated into the virtual environment, similarly to how they would in the real world. Socially, it enables users to interact virtually and in real time with anyone, regardless of their location on the globe. Its capacity to offer greater freedom for creation and sharing is notable. [19]

Medical anatomy has a strong focus on the positioning of the human body and the three-dimensional (3D) interrelationships between organs and features. [20]

How the body is structured, and how these structures adjust their position during movement, aging, or disease, is important for understanding the system as a whole. As such, the opportunity to present content within an entirely virtual world, viewed through stereoscopic 3D (as presented in the metaverse), presents a potential benefit to learners and an exciting concept for educators. [21] Research on the use of different technologies in anatomy education includes studies on virtual reality, mobile augmented reality, web-based computer-assisted learning, and augmented reality.

Each technology has diverse impacts on anatomy education. Consequently, examining the role of the metaverse in anatomy education is crucial. [22-25]

With the rapid introduction of the metaverse into modern life, several applications are already being utilized in education. Therefore, it is essential to comprehend the concept and various types of the metaverse, along with examples of its educational applications. Every new technology considered for educational purposes must be evaluated in the context of integrating instructional technologies into learning environments.

This study aimed to find out the perception changes of the metaverse in anatomy practical sessions.

2. MATERIALS AND METHODS

A cross-sectional, survey-based study was conducted at RAK Medical and Health Sciences University (RAKMHSU), involving undergraduate students of the medical college who were undergoing teaching and training in Anatomy. The study was completed over a period of six months following approval from the RAKMHSU Ethics Committee (RAKMHSU-HEC-87-2023/24-F-M).

1. Study Population and Sample

The study population consisted of MD students in years 1, 3, and 4 from RAK College of Medical Sciences (RAKCOMS), who had not been exposed to the metaverse in anatomy sessions prior to this study. Inclusion criteria comprised all undergraduate students from these college who were not exposed to metaverse-based teaching and training in Anatomy prior to this study and who provided informed consent. Students unwilling to participate, those who had prior experience of the metaverse, and those with visual impairments were excluded.

To prevent adverse effects associated with prolonged immersive environments, like nausea, students with a history of motion sickness or susceptibility to nausea were also excluded.

A census-based sampling method was used, wherein all eligible students were included [275 responded out of a total of 300 students; 92%]. The study consisted of 275 students from different years.

2. Metaverse Training

The first-, third-, and fourth-year MD students were taught anatomy through the metaverse. As anatomy is not included in the second-year MD curriculum, they were excluded as participants. During the training for the third-year MD students, we implemented an innovative and immersive teaching session using a metaverse-based application designed to enhance understanding of the internal and external structures of the heart. This session was integrated into the students' scheduled practical classes to enrich traditional anatomy teaching through a more interactive, three-dimensional learning experience. A total of 140 students (80 male and 60 female) participated, representing a diverse cohort with varying learning preferences.

The metaverse-based instruction was facilitated through the use of extended-reality headsets provided by GIG XR, a company recognized for developing immersive solutions for medical education. We utilized seven headsets, which were shared among students in rotational groups.

This arrangement was intended to allow small groups to take turns exploring the virtual cardiac model in real-time, ensuring that each student has an opportunity to actively engage with the technology. Students using the headsets were able to visualize the heart from multiple perspectives, examine spatial relationships between cardiac structures, and manipulate anatomical features in ways not possible with conventional models or textbooks through "Inside Heart".

Students awaiting their turn remained engaged by observing peers, raising questions, and following the mirrored display of the headset on supporting screens.

Each metaverse session lasted approximately one hour, during which students explored the virtual anatomy of the heart and discussed their observations with peers. Before participation, all students had already completed the foundational teaching on gross cardiac anatomy through lectures and cadaveric practical sessions. This prior exposure is expected to ensure that the metaverse experience functions as a reinforcement tool rather than an introductory exercise, enabling students to revisit familiar structures in an immersive environment and potentially improving their spatial understanding.

To maintain academic rigor and guide learning, one headset was allocated to the anatomy instructor, who joined the students in the virtual environment. The instructor facilitated discussions, highlighted clinically relevant structures, and ensured that the learning objectives remained central throughout the session. Their presence in the metaverse space created a sense of shared exploration and provided reassurance and support to students who initially were hesitant about adapting to the new technology.

Before commencing the session, all 140 students underwent orientation to the metaverse headsets, including instructions on safe use, navigation, and visual adjustment. The orientation also informed the students about potential discomfort, such as motion sickness or dizziness, effects occasionally associated with immersive virtual reality. In accordance with ethical standards, students who report a history of motion sickness or who experience discomfort during the familiarization phase were excluded from participation.

Similarly, first-year MD students used the metaverse for general anatomy through "Inside human", and year 4 MD students used "Inside kidney" for the anatomy of the urinary tract, including the kidneys, ureters, bladder, and urethra.

Overall, the metaverse-enhanced anatomy session was expected to create an engaging and collaborative learning environment. Students not only explored complex cardiac structures but also interacted with one another, shared insights, and strengthened their anatomical understanding.

By combining immersive technology, guided instruction, and peer collaboration, this initiative aimed to create a student-centred, enriched learning experience that complements and enhances traditional approaches to anatomy education.

3. Data Collection Tool

Data were collected using a standardized questionnaire comprising two sections. Section I assessed metaverse acceptance before exposure, while Section II evaluated students' perceptions of integrating the metaverse into conventional anatomy teaching.

Section I used a pre-validated tool [26]. The questionnaire incorporated constructs from the Unified Theory of Acceptance and Use of Technology 2 (UTAUT-2) model to assess technology acceptance. The following seven constructs were measured using a series of statements:

Performance Expectancy, Effort Expectancy, Social Influence, Facilitating Conditions, Hedonic Motivation, Habit, and Behavioral Intention. Each construct was represented by 3–4 items adapted from prior validated instruments. Responses were captured on a 5-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). Individual construct scores were computed by summing the corresponding item scores, with higher scores indicating stronger agreement or greater acceptance. These scores were used to examine differences across gender and academic years.

Section II was meant to identify the perceptions of students towards incorporating the metaverse in traditional anatomy teaching. The questionnaire was formulated after a thorough review of indexed literature from databases like PubMed, Scopus, Web of Science, and Google Scholar. The main themes were mapped with the objectives of the study under five theme headings: Foundational Understanding, Engagement & Motivation, Practical & Clinical Application, Flexibility & Accessibility, as well as Future Recommendations & adoption. In order to ensure the content validity, the questionnaire draft was peer-reviewed by a team of subject-matter experts in anatomy education, educational technology, and educational research in medicine. Clarity, relevance, and measure alignment with the target constructs were evaluated for the items. Suggestions from the team were incorporated to refine item wording and domain representation. Moreover, face validity was established through cognitive interviews in a small sample (n = 8) of students outside the study cohort to check for comprehensibility and interpretability of the items. A pilot test (n = 30) was administered to check for internal consistency reliability with the use of Cronbach's alpha. Items with alpha scores ≥ 0.70 were retained. Items with scores ranging from 0.50 to 0.69 were revised, and items with a score less than 0.50 were dropped. Following revisions, the questionnaire underwent revalidation to confirm that all retained and modified items met the required standards of clarity, relevance, and internal consistency.

The final validated instrument was administered in the main survey. A 5-point Likert scale was used to measure students' responses: Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), and Strongly Agree (5). Each item was assigned a numerical score corresponding to these response categories. Thematic scores were calculated by summing the scores of items grouped under the five mentioned domains. Higher cumulative scores reflected more favourable perceptions toward metaverse integration in anatomy education. These thematic scores were used for gender-wise and year-wise comparisons in the analysis.

4. Statistical Analysis

Descriptive statistics were employed for analysing categorical variables. The student's t-test was used to compare scores, while Pearson's correlation was applied to examine associations among variables. Chi-square tests were used for categorical data, and analysis of variance (ANOVA) was applied to compare differences in continuous variables across subgroups.

3. RESULTS

In our study, the majority of participants were females (n= 172; 62.5%), while 103 were males. The year-wise frequency distribution of participants showed that 116 students were from MD year 1, 58 from MD year 3, and 101 from MD year 4, ensuring representation across different academic levels. Figure 1 depicts the distribution of study participants across the year of study.

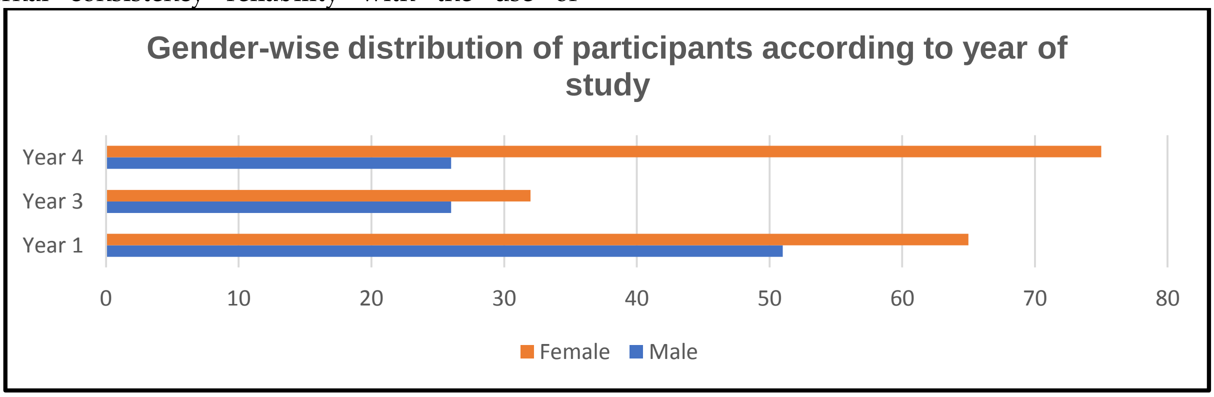

Figure 1: Gender Wise Distribution of Study Participants According to Year of Study.

Table 1A: Gender-Wise Experience with Digital Tools.

Gender*	Extensive (%)	Minimal (%)	Moderate (%)	None (%)	p-value
Female	26 (15.1%)	54 (31.4%)	76 (44.2%)	16 (9.3%)	.386
Male	22 (21.4%)	24 (23.3%)	48 (46.6%)	9 (8.7%)	

[*Gender-wise distribution of prior experience with digital tools shows no statistically significant differences between males and females (p = .386), indicating comparable baseline digital familiarity across groups.]

The gender-wise experience with digital tools was assessed, revealing that 15.1% of females reported extensive experience, while 44.2% had moderate experience. Among males, 21.4% had extensive experience, and 46.6% reported moderate usage. The p-value (= .386) indicated that there was no statistically significant difference in digital tool experience between genders [Table 1A].

Table 1B: MD Year-Wise Experience with Digital Tools.

MD Year*	Extensive (%)	Minimal (%)	Moderate (%)	None (%)	p-value
Year 1	18 (15.5%)	40 (34.5%)	47 (40.5%)	11 (9.5%)	.204
Year 3	11 (19.0%)	18 (31.0%)	24 (41.4%)	5 (8.6%)	
Year 4	20 (19.8%)	25 (24.8%)	55 (54.5%)	3 (3.0%)	

[*Year-wise comparison of digital tool experience shows increasing proficiency from Year 1 to Year 4; however, the differences are not statistically significant (p = .204), indicating broadly similar baseline digital readiness across cohorts.]

When MD year-wise experience with digital tools was assessed, it was observed that 34.5% of Year 1 students had minimal experience, while 54.5% of Year 4 students had moderate experience, reflecting an increase in digital proficiency with academic progression [Table 1B]. However, the p-value (= .204) suggested that these differences were not statistically significant.

Table 2A: Gender-Wise Comfort Level with Technology.

Gender*	Very comfortable (%)	Comfortable (%)	Neutral (%)	Un-comfortable (%)	Very un-comfortable (%)	p-value
Female	38 (22.1%)	79 (45.9%)	49 (28.5%)	4 (2.3%)	2 (1.2%)	.784
Male	26 (25.2%)	43 (41.7%)	28 (27.2%)	3 (2.9%)	3 (2.9%)	

[*Gender-wise comfort with technology shows a similar distribution across all categories, with no significant difference between males and females (p = .784), indicating comparable comfort levels with digital tools.]

Comfort levels with technology were also examined [Table 2A]. In the gender-wise comfort level with technology, 22.1% of females and 25.2% of males reported feeling very comfortable, while 45.9% of females and 41.7% of males were comfortable. The p-value (= .784) indicated no significant gender-based differences in comfort levels.

Table 2B: MD Year-Wise Comfort Level with Technology.

MD Year*	Very comfortable (%)	Comfortable (%)	Neutral (%)	Un-comfortable (%)	Very un-comfortable (%)	p-value
Year 1	39 (33.6%)	52 (44.8%)	22 (19.0%)	2 (1.7%)	1 (0.9%)	.829
Year 3	14 (24.1%)	32 (55.2%)	10 (17.2%)	1 (1.7%)	1 (1.7%)	
Year 4	38 (37.6%)	44 (43.6%)	15 (14.9%)	2 (2.0%)	2 (2.0%)	

[*Across MD years, comfort levels with technology were comparable, with no statistically significant differences (p = .829), indicating consistently high technological comfort throughout the cohorts.]

A similar trend was observed in the MD year-wise comfort level with technology, where 33.6% of Year 1 students felt very comfortable, while 55.2% of Year 3 students were comfortable [Table 2B].

The p-value (= .829) suggested that comfort levels were consistent across academic years.

Table 3A: Gender Wise Difference in Constructs Of UTAUT-2 Scale.

Construct*	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Performance Expectancy	16.24 ± 2.89	15.82 ± 2.75	.236
Effort Expectancy	14.75 ± 2.96	14.02 ± 2.68	**.042**
Social Influence	7.41 ± 1.68	6.92 ± 1.62	**.019**
Facilitating Conditions	14.89 ± 2.74	14.61 ± 2.69	.410
Hedonic Motivation	12.42 ± 2.36	12.18 ± 2.44	.421
Habit	14.22 ± 3.28	13.04 ± 3.39	**.005**
Behavioral Intention	11.32 ± 2.45	10.76 ± 2.52	.071

[*Gender-wise comparison of UTAUT-2 constructs shows generally similar perceptions, with significant differences (p< .05) observed only in Effort Expectancy, Social Influence, and Habit, where males reported higher scores. Other constructs showed no statistically significant variation (p> .05) .]

The table presents a gender-wise comparison of key constructs from the UTAUT-2 model, measuring differences in perceptions between male and female participants. three constructs showed statistically significant differences between genders [Table 3A]. Effort Expectancy (14.75 ± 2.96 vs. 14.02 ± 2.68, p = .042) was significantly higher among males, indicating that they found technology easier to use compared to females. Social Influence (7.41 ± 1.68 vs. 6.92 ± 1.62, p = .019) also showed a significant difference, suggesting that males perceived a stronger influence from peers or societal expectations in their technology use.

Also, a notable difference was observed in Habit (14.22 ± 3.28 vs. 13.04 ± 3.39, p = .005), indicating that males were more likely to integrate technology into their daily routines.

Table 3B: MD Year-Wise Difference in Constructs Of UTAUT-2 Scale.

Construct*	Year 1 (Mean ± SD)	Year 3 (Mean ± SD)	Year 4 (Mean ± SD)	p-value
Performance Expectancy	16.16 ± 3.08	15.10 ± 2.56	16.17 ± 2.53	**.036**
Effort Expectancy	15.01 ± 3.02	13.82 ± 2.56	15.03 ± 3.02	**.023**
Social Influence	7.25 ± 1.76	6.36 ± 1.57	7.36 ± 1.65	**.0008**
Facilitating Conditions	14.67 ± 2.85	14.57 ± 2.63	14.84 ± 2.80	.760
Hedonic Motivation	12.51 ± 2.45	12.15 ± 2.33	12.27 ± 2.03	.560
Habit	13.86 ± 3.40	12.50 ± 3.48	14.62 ± 3.08	**.0006**
Behavioral Intention	10.90 ± 2.48	10.74 ± 2.58	11.70 ± 2.38	**.021**

[*MD year-wise comparison of UTAUT-2 constructs shows significant differences in several domains, with Year 4 students generally reporting higher performance expectancy, effort expectancy, habit, and behavioral intention, while Year 3 students consistently showed lower scores across multiple constructs.]

The table compares UTAUT-2 constructs across MD Year 1, Year 3, and Year 4 students, showing differences in perceptions of technology use [Table 3B].

Significant differences were observed in Performance Expectancy (p = .036), Effort Expectancy (p = .023), Social Influence (p = .0008), Habit (p = .0006), and Behavioural Intention (p = 0.021). Year 4 students had the highest scores in most of these constructs, particularly in Performance Expectancy (16.17 ± 2.53) and Habit (14.62 ± 3.08), suggesting greater confidence in and integration of technology.

Year 3 students had the lowest scores, especially in Effort Expectancy (13.82 ± 2.56) and Social

Influence (6.36 ± 1.57), indicating lower perceived ease of use and peer influence.

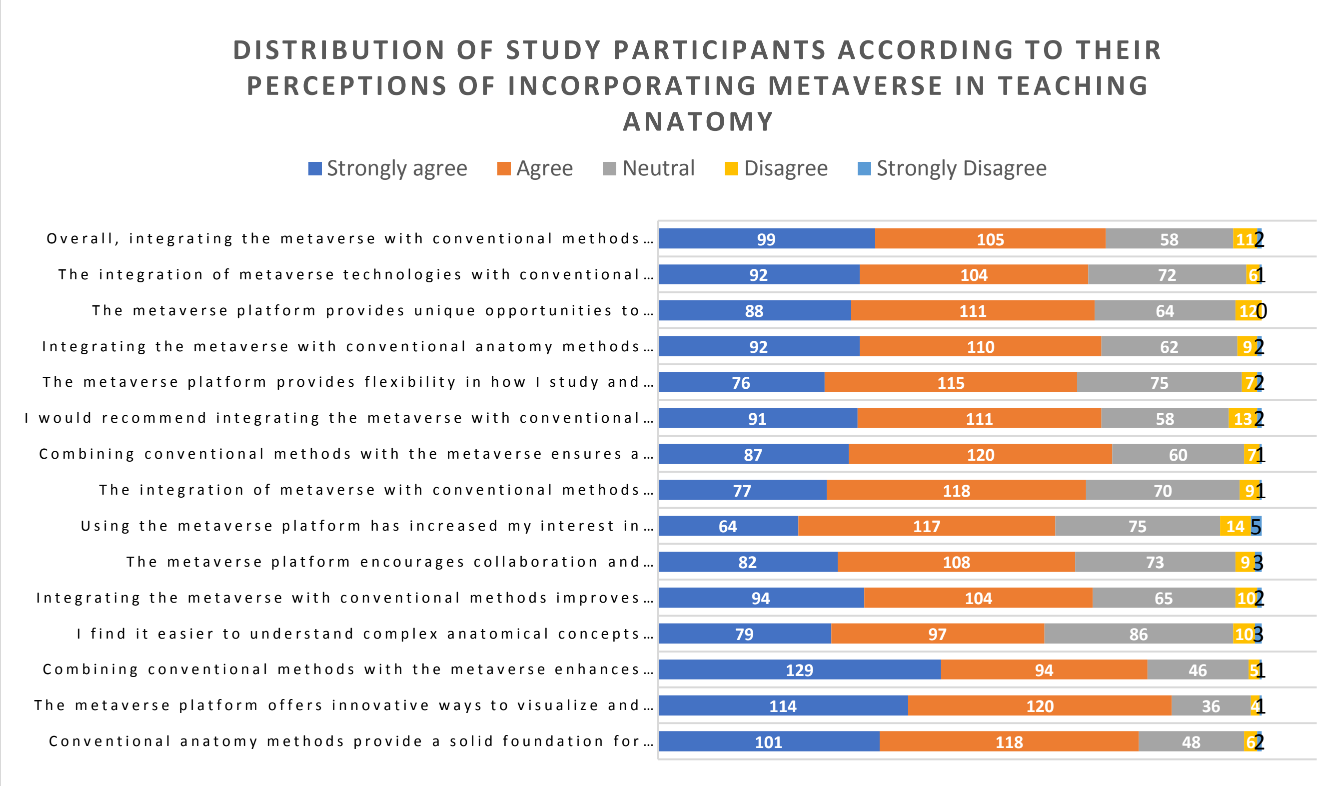

Figure 2: Distribution Of Study Participants According to Their Perceptions of Incorporating the Metaverse in Teaching Anatomy.

The figure 2 presents the frequency distribution of participant responses to a series of statements evaluating the integration of the metaverse platform with conventional anatomy education methods. Overall, the responses indicate a generally positive perception of the metaverse-enhanced anatomy learning experience. The majority of participants selected Agree or Strongly Agree for most statements, particularly those addressing visualization of 3D structures, engagement, and innovative learning experiences. Neutral responses were also common for certain items, suggesting areas where the perceived impact may be variable or context-dependent. Few participants selected negative responses (Disagree or Strongly Disagree), indicating limited opposition to the integration of the metaverse in anatomy education.

Table 4A: Gender-Wise Total Scores (Mean ± SD)

Themes*	Female (Mean ± SD)	Male (Mean ± SD)	p-value
Foundational Understanding & Learning Enhancement	20.02 ± 3.40	20.82 ± 2.99	**.043**
Engagement & Student Motivation	11.63 ± 2.29	11.95 ± 2.37	.274
Practical & Clinical Applications	11.73 ± 2.24	12.37 ± 2.06	**.017**
Flexibility & Accessibility	7.98 ± 1.42	8.48 ± 1.33	**.004**
Future Recommendations & Adoption	7.91 ± 1.67	8.27 ± 1.54	.070

[*Gender-wise comparison of theme-wise total scores shows generally comparable perceptions, with males reporting significantly higher scores in foundational understanding, practical applications, and flexibility, while other themes showed no significant differences.]

This table presents a gender-wise comparison of total scores across five key themes. Statistically significant differences were observed in Foundational Understanding & Learning Enhancement (p = .043), Practical & Clinical Applications (p = .017), and Flexibility &

Accessibility (p = .004) [Table 4A]. Males scored higher than females in all three, indicating that they found technology more adaptable.

Table 4B: MD Year-Wise Total Scores (Mean ± SD)

Themes*	Year 1 (Mean ± SD)	Year 3 (Mean ± SD)	Year 4 (Mean ± SD)	p- value
Foundational Understanding & Learning Enhancement	20.04 ± 3.45	20.63 ± 3.08	20.28 ± 3.08	.520
Engagement & Student Motivation	11.61 ± 2.39	12.04 ± 2.14	11.52 ± 2.39	.380
Practical & Clinical Applications	11.90 ± 2.25	12.07 ± 2.11	11.93 ± 2.22	.880
Flexibility & Accessibility	8.22 ± 1.46	8.19 ± 1.35	8.07 ± 1.40	.720
Future Recommendations & Adoption	7.97 ± 1.65	8.20 ± 1.57	7.97 ± 1.64	.630

[*MD year-wise comparison of theme-wise total scores shows no statistically significant differences across cohorts, indicating consistent perceptions of metaverse-based anatomy learning among students in Years 1, 3, and 4.]

This table compares total scores across academic years. Unlike the gender-wise analysis, no statistically significant differences were found across years. The scores remained relatively stable across Foundational Understanding, Engagement & Motivation, Practical Applications, Flexibility, and Future Recommendations, suggesting that perceptions of technology-related learning benefits were consistent regardless of academic progression [Table 4B].

4. DISCUSSION

This study examined medical students' acceptance of metaverse-based anatomy learning, revealing nuanced variations by gender and year of study. Overall, both male and female students demonstrated strong receptivity, with no significant gender differences in prior digital tool experience or general technology comfort, indicating comparable baseline digital preparedness.

Gender differences emerged in specific acceptance constructs. Male students reported significantly higher “Effort Expectancy” (perceiving the tool as easier to use) and “Habit” (tendency for routine integration), alongside slightly higher “Social Influence” (perceived peer/instructor support). This suggests males found the platform more intuitive and were more likely to incorporate it routinely, potentially due to greater prior exposure or confidence. Conversely, while equally positive about the metaverse's usefulness (“Performance Expectancy” was high in both groups), female students may require additional encouragement or training to achieve similar ease-of-use familiarity. This aligns with prior research indicating women often report lower technology self-efficacy and higher computer anxiety, increasing perceived effort requirements [27]. The higher male “Social Influence” contrasts with some studies where females are more peer-influenced; this divergence may be cohort-specific, perhaps driven by enthusiastic male advocates. The absence of gender gaps in “Performance Expectancy”, “Facilitating Conditions”, or “Behavioral Intention” is encouraging, indicating both genders recognized the metaverse's value. This supports recent indications that the gender divide in technology acceptance is narrowing in academia when adequate support is provided.

Year-wise comparisons showed a progression in acceptance from first-year to senior students, with a notable dip in third-year students. Fourth-year students reported the highest “Performance Expectancy” (confidence in learning enhancement) and “Behavioral Intention”, along with the strongest “Habit”. Second-year students scored significantly lower on these measures (first-years were typically intermediate). Senior students, with greater clinical exposure, likely better appreciate the utility of 3D immersive anatomy for clinical preparation, perceiving greater benefits and being more inclined to habitual use. The third-year "dip" may reflect waning enthusiasm during intense mid-phase coursework (e.g., pathology/physiology), where the metaverse's immediate relevance to current studies may be less apparent, dampening perceived ease of use and peer influence. Engagement likely rebounded in the fourth year as focus returned to clinical anatomy. Although not all constructs differed by year (e.g., technology comfort, facilitating conditions), the areas of difference align with an experiential learning curve. Prior studies suggest exposure strengthens perceived usefulness and routine use; our data support this, as students further along the curriculum (with more anatomy application opportunities) found greater value and formed habits. Future implementations should address the sophomore slump by better integrating the metaverse into second-year courses.

Comparing with previous immersive technology research reveals parallels. Consistent with our participants' positive perceptions, literature indicates VR/AR tools enhance anatomy learning [28]. Their finding of higher test scores "with lower cognitive load" using AR for neuroanatomy aligns with our students' perception that the metaverse improved foundational understanding, both indicate immersive 3D visualization clarifies complex spatial relationships better than traditional methods alone. The noted benefits of flexibility ("anytime, anywhere" access) and learning satisfaction mirror our students' high valuation of "Flexibility & Accessibility" [28]. Enhanced engagement/motivation are frequently cited VR/AR benefits. A systematic review reporting improved interest, motivation, and confidence aligns closely with our high ratings for the metaverse's ability to increase "Engagement & Motivation" [29]. Both genders and all years similarly acknowledged the platform as stimulating and enjoyable (no differences in "Engagement & Motivation" or "Hedonic Motivation"), reflecting broad interest in the novelty and interactivity. Qualitative comments highlighted the "fun", gamified exploration. This intrinsic motivation is crucial, as per UTAUT-2, for driving continued educational technology use.

Our findings on '" Social Influence" and "Facilitating Conditions" are also supported. A study, also applying UTAUT-2 to metaverse anatomy learning, found "Social Influence" positively affected intention [26]. While males in our study felt slightly more social encouragement, overall students acknowledged peer/faculty encouragement's role (mean ~7/10). Creating a culture of sharing positive experiences can boost adoption. They also identified "Facilitating Conditions" (support/resources availability) as a significant predictor of intention [26]. In our study, guaranteed access to hardware and support likely contributed to high acceptance, with no qualitative complaints about technical barriers. This underscores that replicating positive outcomes elsewhere requires strong facilitating conditions (adequate devices, stable software, IT support, curriculum integration). Without this infrastructure, student interest may wane.

In summary, our results reinforce and extend the consensus from prior VR/AR research: immersive technologies can enrich anatomy education by improving understanding, engagement, and perceived utility. Students in our study, regardless of gender or academic stage, recognized clear benefits of the metaverse, from enhanced visualization of anatomy to greater flexibility in learning, echoing themes reported in earlier studies of virtual anatomy learning. At the same time, the subtle demographic differences we observed (e.g. men finding the tool a bit easier, and seniors valuing it more than mid-level students) highlight that one size may not fit all in implementation. These differences, while not impeding overall success, suggest the need for targeted strategies (such as extra onboarding for less tech-confident groups and maintaining engagement during academically heavy periods) to ensure every student can fully benefit from the metaverse. Our discussion is rooted in the UTAUT-2 framework, which proves valuable for interpreting how factors like effort, social influence, and habit mediate educational technology uptake. By contextualizing our findings with this model and related studies, we affirm that the metaverse's impact on student learning is multidimensional, enhancing not just knowledge gains but also motivation and collaboration, and these dimensions are perceived somewhat differently across subgroups of learners. With the implementation of a Competency-Based Framework and the incorporation of Entrustable Professional Activities in medical education in the UAE, the metaverse can be an invaluable tool for learning [30]. Ultimately, integrating metaverse technology into anatomy education holds significant promise, provided that educators remain cognizant of the diverse student needs and perceptions that accompany its use.

5. CONCLUSION

This study, grounded in UTAUT-2, found broadly positive medical student perceptions of metaverse-based anatomy learning. Quantitatively, students reported high "Performance Expectancy" (viewing it as useful for mastering anatomy) and strong "Behavioral Intention" to continue use. Baseline digital experience and technology comfort showed no significant gender or year differences, indicating equitable starting conditions. However, males reported slightly higher "Effort Expectancy" (ease of use) and "Habit" formation, while second-year students showed lower enthusiasm than first- and third-years on some metrics, though differences were small.

Qualitatively, students highlighted significant educational benefits:

- Enhanced Understanding: The immersive 3D environment uniquely clarified complex spatial relationships and structures (e.g., virtual dissection, observing variations, repeated practice), surpassing textbooks or cadavers alone.
- Increased Engagement & Motivation: Game-like interactivity, novelty, and features (e.g., VR anatomy quizzes) made learning highly engaging and enjoyable.
- Clinical Relevance: Virtual surgeries and clinical case simulations effectively bridged theory and practice, connecting preclinical anatomy to patient care and enhancing clinical readiness.
- Flexibility & Accessibility: 24/7 access to the "virtual cadaver" supported exam review, accommodated schedules, reduced anxiety, and boosted confidence.

Collectively, these findings demonstrate that thoughtfully integrated metaverse tools effectively complement (not replace) cadaveric dissection. They enhance anatomical understanding, engagement, and accessibility, while providing safe, repetitive exposure to lifelike clinical scenarios. This early clinical practice improves students' preparedness for real patient care and smooths the transition to clinical environments. Metaverse technology thus serves as a potent complementary tool, broadening educational reach and better equipping students for both academic success and future clinical practice.

Future Directions

Building on the encouraging outcomes of this study, we recommend several future directions to maximize the potential of metaverse technology in anatomy and medical education:

- Pedagogical Integration: Development of hybrid curricula strategically blending metaverse sessions (e.g., pre/post-lab VR modules for spatial reinforcement) with traditional dissection, allocating specific time/credits and defining virtual competencies.
- Active Learning Design: Implementation of student-centered metaverse activities (e.g., collaborative virtual patient diagnosis, problem-based dissection tasks) for deeper learning and critical thinking.
- Faculty Development / Instructor Facilitation: Training of educators to effectively guide and ensure inclusive participation within the virtual environment.
- Haptic Technology: Incorporation of tactile feedback interfaces (e.g., force-feedback gloves) to enhance realism and psychomotor skill training. Technical optimization can be done to improve graphics, reduce hardware bulk (e.g., lighter headsets/AR glasses), ensure cross-platform access, and minimize latency.
- AI Personalization: Integration of AI for adaptive learning paths, real-time feedback, intelligent virtual tutors, and generating diverse clinical scenarios.
- Infrastructure & Equity: Investment in sustainable hardware/software infrastructure and ensure equitable access (e.g., device availability, cost-effective AR options).
- Ethical Frameworks & Research: Establishing guidelines for safety, data privacy, and ethical content; promote rigorous effectiveness research to secure accreditation support and ensure systematic, sustainable integration.

Limitations:

1. The study's cross-sectional nature restricts causal inference
2. The study used self-reported questionnaires, which may be influenced by social desirability bias, recall inaccuracies
3. Single-centre study, the results cannot be generalised.

Ethics Approval and Consent to Participate: The study was approved by the Institutional Review Committee bearing approval number RAKMHSU-HEC-87-2023/24-F-MA. Written consent was obtained from each participant in this study for their participation.

Clinical Trial Number: Not Applicable

Availability Of Data and Materials: All the data generated during this study are part of this article. Raw data can be obtained from the corresponding authors on reasonable request. It has not been deposited in any repository.

Competing Interests: The authors declare that they have no competing interests.

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REFERENCES

Abu-Hijleh MF, Hamdi NA, Moqattash ST, Harris PF, Heseltine GFD. Attitudes and reactions of Arab medical students to the dissecting room. Clin Anat. 1997;10(4):272–8.

Arraez-Aybar LA, Sanchez-Montesinos I, Mirapeix RM, Mompeo-Corredera B, Sanudo-Tejero JR. Relevance of human anatomy in daily clinical practice. Ann Anat. 2010;192(6):341–8.

Chytas D, Salmas M, Demesticha T, Troupis TG. The important role of interaction when virtual reality is used for anatomy education. Anat Sci Educ. 2022; 15:636–7.

Duncan-Vaidya EA, Stevenson EL. The effectiveness of an augmented reality head-mounted display in learning skull anatomy at a community college. Anat Sci Educ. 2021;14(2):221–31. doi:10.1002/ase.1998.

El Naggar MA, Almaeen AH. Student's perception towards medical-simulation training as a method for clinical teaching. J Pak Med Assoc. 2020;70(4):618–23.

Evans EJ, Fitzgibbon GH. The dissecting room: reactions of first year medical students. Clin Anat. 1992;5(4):311–20.

Finkelstein P, Mathers LH. Post-traumatic stress among medical students in the anatomy dissection laboratory. Clin Anat. 1990;3(3):219–26.

Granger NA. Dissection laboratory is vital to medical gross anatomy education. Anat Rec B New Anat. 2004;281(1):6–8.

Hamid ARAH, Ayasasmita FS, Yusuf PA. Metaverse in medical education. Med J Indones. 2023;32(2):67–74.

Henrique-Sanches BC, Cecilio-Fernandes D, Costa RRDO, Almeida RGDS, Etchegoyen FF, Mazzo A. Implications of clinical simulation in motivation for learning: scoping review. Einstein (São Paulo). 2024;22:RW0792.

Itoh Y, Chen Y, Iida K, Shiiki M, Mitsubuchi K. Experiment of metaverse learning method using anatomical 3D object. In: Spencer SN, editor. Proceedings of the 8th International Conference on Virtual Reality Continuum and Its Applications in Industry (VRCAI'09); 2009 Dec 14–15; Yokohama, Japan. New York (NY): Association for Computing Machinery. 2009; 289–94.

Kalınkara Y, Özdemir O. Anatomy in the metaverse: exploring student technology acceptance through the UTAUT2 model. Anat Sci Educ. 2024;17:319–36. doi:10.1002/ase.2353.

Kar SS, Dube R, George BT, Bairy LK, Hajeer AH, Matalka IIA. Implementation of United Arab Emirates competency framework for medical education in undergraduate medical curriculum. BMC Medical Education. 2025;25:782. https://doi.org/10.1186/s12909-025-07342-0

Korf HW, Wicht H, Snipes RL, Timmermans JP, Paulsen F, Rune G, et al. The dissection course—necessary and indispensable for teaching anatomy to medical students. Ann Anat. 2008;190(1):16–22.

Küçük S, Kapakin S, Göktaş Y. Learning anatomy via mobile augmented reality: Effects on achievement and cognitive load. Anatomical Sciences Education. 2016;9(5):411-421. https://doi.org/10.1002/ase.1603

Küçük S, Kapakin S, Göktaş Y. Medical faculty students' views on anatomy learning via mobile augmented reality technology. J High Educ Sci. 2015;3:316–23.

Kye B, Han N, Kim E, Park Y, Jo S. Educational applications of metaverse: possibilities and limitations. J Educ Eval Health Prof. 2021;18:1–8.

Li Q, Duan H, Zhou X, Sun X, Tao L, Lu X. The use of metaverse in medical education: A systematic review. Clinical Medicine. Published online April 2025:100315. https://doi.org/10.1016/j.clinme.2025.100315

Li Q, Duan H, Zhou X, Sun X, Tao L, Lu X. The use of metaverse in medical education: a systematic review. Clin Med. 2025;100315.

McNulty JA, Halama J, Espiritu B. Evaluation of computer-aided instruction in the medical gross anatomy curriculum. Clin Anat. 2004;17(1):73–8.

Older J. Anatomy: a must for teaching the next generation. Surgeon. 2004;2(2):79–90.

Parker LM. Anatomical dissection: why are we cutting it out? Dissection in undergraduate teaching. ANZ J Surg. 2002;72(12):910–2.

Sandrone S. Medical education in the metaverse. Nat Med. 2022;28(12):2456–7.

Tan TF, Li Y, Lim JS, Gunasekeran DV, Teo ZL, Ng WY, et al. Metaverse and virtual health care in ophthalmology: opportunities and challenges. Asia Pac J Ophthalmol. 2022;11:237–46.

Topuz Y. Comparison of virtual reality and three-dimensional desktop materials in anatomy education in terms of academic achievement and cognitive load [dissertation]. Istanbul: Marmara University, Institute of Educational Sciences, Department of Computer and Instructional Technologies in Education; 2018.

Turney BW. Anatomy in a modern medical curriculum. Ann R Coll Surg Engl. 2007;89(2):104–7.

Tyagi V, Singh H, Puri N, Tyagi P. Exploring the potential of the metaverse in higher education: a bibliometric analysis. J Content Community Commun. 2023;17:219–33.

Venkatesh V, Morris MG, Davis GB, Davis FD. User Acceptance of Information technology: toward a Unified View. MIS Quarterly. 2003;27(3):425-478. https://doi.org/10.2307/30036540

von Lüdinghausen M. The goal of dissection in clinically oriented teaching. Clin Anat. 1992;5(6):488–9.

Willan PL, Humpherson JR. Concepts of variation and normality in morphology: important issues at risk of neglect in modern undergraduate medical courses. Clin Anat. 1999;12(3):186–90.