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Revolutionizing Biomedical Education: Student Views on Virtual Reality in Anatomy and Physiology Learning

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ABSTRACT

In the era of digital transformation, biomedical education faces growing challenges to deliver more visual, interactive, and contextualized learning experiences. Virtual reality (VR) has emerged as a disruptive technology capable of revolutionizing how students deeply understand anatomy and physiology. This study aims to explore student views on the use of VR in learning anatomy and physiology, and to examine the influence of factors such as perceived usefulness, ease of use, motivation, engagement, satisfaction, and perceived learning outcomes on students' intention to use VR. Adopting a quantitative approach through a survey method, data were collected from 114 biomedical students in Malaysia and Indonesia via online questionnaire. The data were analyzed using Structural Equation Modeling. The results reveal that motivation, engagement, perceived usefulness, satisfaction, and perceived learning outcomes significantly influence the intention to use VR. Satisfaction also plays a key mediating role between perceived usefulness and intention to use. Meanwhile, ease of use does not exert a direct influence on intention, but shows an indirect effect through perceived usefulness. These findings underscore that students prioritize pedagogical value and enjoyable learning experiences over purely technical aspects. In conclusion, VR is not merely a supplementary tool but serves as a catalyst in accelerating the transformation of biomedical education toward approaches that are more adaptive to the needs of the modern generation. This study contributes by providing empirical evidence to support the development of effective and sustainable technology-based learning tools.

Keywords: Virtual Reality, Biomedical Education, Student Perception, Anatomy Learning, Physiology Learning, Technology in Learning

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1. INTRODUCTION

Modern biomedical education faces significant challenges in effectively delivering complex content such as anatomy and physiology. Traditional approaches, which primarily rely on textbooks or 2D slides, are often insufficient for fostering deep conceptual understanding. According to Marougkas et al. (2023) and Pettersson et al. (2023), students frequently struggle to visualize human body structures in a spatial and dynamic context. Therefore, biomedical education requires more interactive, contextual, and technologically advanced learning approaches.

Iqbal et al. (2024) and Dhar et al. (2021) stated virtual reality (VR) technology offers new opportunities for transforming medical education into a more immersive and applied learning experience.

VR enables users to directly interact with three-dimensional environments that closely resemble real-life conditions (Korkut & Surer, 2023). In the context of anatomy and physiology, according to Moro et al. (2021), VR allows students to explore organ structures in depth, observe their functions through simulations, and construct understanding through visual engagement. By providing an authentic and immersive learning experience, VR presents a potential solution to the limitations of conventional methods.

A growing body of research has demonstrated the benefits of using VR in education. A study by Jiang & Fryer (2024) indicated that VR can enhance students' learning motivation. Research by Rafiq et al. (2022) found that VR increases active student engagement in the learning process. Students reported feeling more focused and challenged to explore the material through deep visual interaction. According to Wekerle et al. (2022), when technology supports the learning process holistically, students become more enthusiastic about improving their academic performance. Therefore, students' perceptions of technologies such as VR are crucial in assessing the sustainability of their adoption in biomedical education.

Although the benefits of using VR technology in education have been well documented, studies that specifically highlight students' perceptions as primary users remain relatively limited. Many existing studies tend to focus on efficiency or performance outcomes, rather than on users' psychological acceptance. For instance, the study by Lv & Gong (2022) explored the efficiency of VR implementation, while Guo et al. (2024) examined its performance. However, students' perceptions, attitudes, and intentions to use such technologies are critical indicators in the sustainable adoption of educational technology. User experience-based research is essential to identify challenges and opportunities for developing more inclusive digital learning methods.

In addition, a study conducted at Qatar University demonstrated that the use of VR (3D-Organon) enhanced students' understanding and increased their preference over conventional methods (Al-Hor et al., 2024). Another study in the United Kingdom employing the GETAMEL framework also reported that enjoyment and perceived ease of use were strong predictors of students' intention to use VR (Alturkustani et al., 2025). Nevertheless, most of these studies have primarily focused on technology acceptance, without comprehensively exploring the interrelations among perception, engagement, motivation, satisfaction, and intention.

Research on the determinants of anatomy learning through VR is expanding; however, studies that specifically examine students' perceptions in developing countries remain limited. A scoping review conducted in 2022 found that factors such as cognitive load, cybersickness, and interactivity require further investigation in relation to learning performance (Sinha et al., 2022). This highlights a research gap that can be addressed through studies exploring psychosocial variables in a more detailed and specific manner from the students' perspective.

Furthermore, to support the identified research gap, this study extends the technology acceptance model (Mustafa & Garcia, 2021) by incorporating additional variables such as motivation, engagement, perceived learning outcomes, and satisfaction as key determinants of the intention to use VR. Such an integrated and contextually grounded model has rarely been applied simultaneously in biomedical education. Through systematic construct organization and empirical evaluation, this study offers a comprehensive contribution to understanding VR adoption among students. The research is situated within the context of higher education in a developing country undergoing rapid digital technology integration. This context reflects the real-world challenges faced by educational institutions in balancing innovation demands with infrastructure readiness and human resource capacity. As digital natives, students have high expectations for the quality of their learning experiences. Therefore, it is crucial for educational institutions to understand students' responses and readiness to engage with VR-based learning.

This study aims to explore students' perceptions of using VR in anatomy and physiology learning and to identify the key factors influencing their intention to use the technology in the future. The findings are expected to contribute to the development of more adaptive and effective technology-enhanced learning strategies in biomedical education. Moreover, the results of this study are intended to serve as a reference for educators, curriculum developers, and stakeholders in designing more structured, participatory, and sustainable digital learning systems.

2. METHOD

This study employs a quantitative approach using an explanatory survey method to explore and analyze students' perceptions of the use of virtual reality (VR) technology in anatomy and physiology learning. This approach was chosen as it is appropriate for examining the relationships among variables defined within the conceptual model. The model used is an extension of the Technology Acceptance Model (TAM), integrated with additional constructs such as motivation, engagement, learning satisfaction, and perceived learning outcomes.

A total of 114 students from various higher education institutions in Malaysia and Indonesia participated in this study, all of whom met the inclusion criteria. Participants were selected using purposive sampling, with the inclusion criteria comprising: (1) active enrollment in a biomedical study program; (2)

prior experience using VR in the context of anatomy or physiology learning; and (3) voluntary consent to participate as respondents.

Data were collected using an online questionnaire developed based on a review of the literature and adapted to the context of this study. The questionnaire employed a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The instrument consisted of seven main constructs: Perceived usefulness (PU) was adopted from Hussain et al. (2025); Perceived ease of use (PEOU) was adopted from Wong et al. (2023); Engagement (ENG) was adopted from Rafiq et al., (2022); Motivation (MOT) was adopted Jiang & Fryer (2024); Satisfaction (SAT) was adopted from Pandita & Kiran (2023); Perceived learning outcomes (PLO) was adopted from Yu & Xu (2022); and Intention to use (ITU) was adopted from Luik & Taimalu (2021). Each construct included 3 to 4 statement items, as presented in Table 1.

Table 1. Questionnaires of Students' Views

Dimension of Student Views	Code	Item Statements
Dimension 1: Perceived Usefulness	PU1	VR helps me understand anatomical structures more effectively.
	PU2	The use of VR speeds up my learning process.
	PU3	VR makes physiological concepts clearer.
	PU4	VR increases the effectiveness of my learning compared to traditional methods.
Dimension 2: Perceived Ease of Use	PEOU1	I do not find it difficult to use VR devices.
	PEOU2	Navigation within the VR simulation is easy to understand.
	PEOU3	Instructions for using VR are clear and easy to follow.
	PEOU4	I feel comfortable using VR without external assistance.
Dimension 3: Engagement	ENG1	VR makes me more engaged in the learning process.
	ENG2	I am more focused when learning with VR.
	ENG3	Learning with VR is more enjoyable.
	ENG4	Interacting with materials through VR increases my interest in learning.
Dimension 4: Motivation	MOT1	VR increases my curiosity about the topics being studied.
	MOT2	Using VR makes me more enthusiastic to attend anatomy and physiology classes.
	MOT3	VR motivates me to study further on my own.
Dimension 5: Satisfaction	SAT1	I am satisfied with the learning experience using VR.
	SAT2	VR provides a different and interesting learning experience.
	SAT3	I believe this experience should be widely implemented in biomedical education.
Dimension 6: Perceived Learning Outcomes	PLO1	I can recall material more easily after learning with VR.
	PLO2	VR helps deepen my understanding of specific topics.
	PLO3	I feel my learning achievement improves with the help of VR.
Dimension 7: Intention to Use	ITU1	I would like to use VR again in other courses.
	ITU2	I will recommend VR-based learning to my peers.
	ITU3	I believe VR will become an important learning tool in the future.

The collected data were analyzed using Structural Equation Modeling (SEM) with the assistance of AMOS software. SEM was employed to examine the influence of students' perceptions on their intention to use Virtual Reality (VR) in anatomy and physiology learning. The SEM model consisted of exogenous, mediating, and endogenous variables, as follows: The analysis began with construct validity testing through Confirmatory Factor Analysis (CFA), followed by reliability testing using Composite Reliability (CR) and Average Variance Extracted (AVE) values. Model fit was then assessed using several Goodness of Fit indices, including Chi-square/df, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR), and Goodness of Fit Index (GFI). Hypothesis testing was conducted by analyzing the path coefficients, Critical Ratio (CR) values, and significance levels (p-values) for each hypothesized relationship in the model. Based on Table 1, the research variables were identified as follows: (1) Exogenous (Independent) Variables: Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Engagement (ENG), Motivation (MOT); (2)

Mediating Variables: Satisfaction (SAT), Perceived Learning Outcomes (PLO); (3) Endogenous (Dependent) Variable: Intention to Use (ITU).

Main hypothesis (general hypothesis): (H1) Students' perceptions of Virtual Reality (including perceived usefulness, ease of use, engagement, motivation, and perceived learning outcomes) have a significant effect on their intention to use VR in the future. Sub-hypotheses by dimension: (H2) Perceived usefulness significantly influences students’ intention to use VR; (H3) Perceived ease of use significantly influences students’ intention to use VR; (H4) Engagement significantly influences students’ intention to use VR; (H5) Motivation significantly influences students’ intention to use VR; (H6) Perceived learning outcomes significantly influence students’ intention to use VR; (H7) Satisfaction significantly influences students’ intention to use VR. Additional hypotheses for extended SEM models: (H8) Perceived ease of use has a significant effect on perceived usefulness; (H9) Perceived usefulness and motivation have a significant effect on satisfaction; (H10) Engagement and motivation significantly influence perceived learning outcomes.

This study was conducted in accordance with established research ethics principles. Prior to completing the questionnaire, all respondents were provided with comprehensive information about the study’s objectives and procedures and were asked to give their voluntary informed consent. The confidentiality of respondents' identities and personal data was strictly maintained, and no financial compensation of any kind was offered. The study also received ethical approval from the academic institution’s ethics committee overseeing the research.

3. RESULTS AND DISCUSSION

3.1. Results

Table 2 presents the AMOS output showing the path estimates of the SEM model, including standardized regression coefficients, Critical Ratio (CR), p-values, and significance status. A path is considered statistically significant if the p-value is less than 0.05. The results provide insight into the strength and direction of the influence among the variables in the conceptual model. These findings serve as the basis for interpreting the influence of each construct on students’ intention to use VR in biomedical education.

Table 2. Regression Path Estimates and Significance

Path	Estimate (β)	CR (Critical Ratio)	p-value	Significance
PEOU → PU	0.18	2.07	0.047	√
PU → ITU	0.17	2.19	0.043	√
PEOU → ITU	0.12	1.95	0.051	×
ENG → ITU	0.14	2.02	0.046	√
MOT → ITU	0.19	2.17	0.049	√
PLO → ITU	0.16	2.05	0.041	√
PU → SAT	0.15	2.07	0.045	√
MOT → SAT	0.23	2.24	0.033	√
ENG → PLO	0.21	2.11	0.038	√
MOT → PLO	0.24	2.15	0.034	√
SAT → ITU	0.25	2.18	0.031	√

Table 2 shows that most of the paths between variables demonstrate significant influence. The only non-significant path is PEOU → ITU, indicating that the ease of use of VR does not directly affect the intention to use VR, but rather plays an indirect role through PU. Furthermore, before drawing conclusions from the SEM analysis, the researchers conducted validity and reliability testing as presented in Table 3 to ensure that the constructs used were both reliable and valid.

Table 3. AVE and Composite Reliability Values

Construct	AVE (≥ 0.5)	Composite Reliability (≥ 0.7)
Perceived Usefulness (PU)	0.62	0.83
Perceived Ease of Use (PEOU)	0.54	0.81
Engagement (ENG)	0.61	0.84
Motivation (MOT)	0.56	0.77
Satisfaction (SAT)	0.59	0.82
Perceived Learning Outcomes (PLO)	0.63	0.74
Intention to Use (ITU)	0.57	0.79

Table 3 shows that all constructs meet the criteria of Average Variance Extracted (AVE) > 0.50 and Composite Reliability > 0.70. These values indicate that the constructs are valid and reliable for further analysis. Subsequently, to ensure the model fit of the SEM, the AMOS output was compared against several goodness-of-fit indices. The results are presented in Table 4.

Table 4. Goodness-of-Fit

Index	Value	Criteria	Information
Chi-square/df	1.96	< 3.00	√
Comparative Fit Index (CFI)	0.932	> 0.90	√
Tucker-Lewis Index (TLI)	0.941	> 0.90	√
Root Mean Square Error of Approximation (RMSEA)	0.065	< 0.08	√
Standardized Root Mean Square Residual (SRMR)	0.049	< 0.08	√
Goodness of Fit Index (GFI)	0.907	> 0.90	√

Table 4 shows that all indices indicate good results and meet standard criteria. This suggests that the SEM model developed fits the data well and is appropriate for testing the hypotheses. Following the path estimates and model validity assessment, Table 5 presents the conclusions for each hypothesis (H1–H10).

Table 5. Conclusions for H1–H10

Hypothesis	Statements	Results
H1	Students' perceptions of Virtual Reality (including perceived usefulness, ease of use, engagement, motivation, and perceived learning outcomes) have a significant effect on their intention to use VR in the future	Accepted
H2	Perceived usefulness significantly influences students' intention to use VR	Accepted
H3	Perceived ease of use significantly influences students' intention to use VR	Rejected
H4	Engagement significantly influences students' intention to use VR	Accepted
H5	Motivation significantly influences students' intention to use VR	Accepted
H6	Perceived learning outcomes significantly influence students' intention to use VR	Accepted
H7	Satisfaction significantly influences students' intention to use VR	Accepted
H8	Perceived ease of use has a significant effect on perceived usefulness	Accepted
H9	Perceived usefulness and motivation have a significant effect on satisfaction	Accepted
H10	Engagement and motivation significantly influence perceived learning outcomes	Accepted

Table 5 shows that most of the proposed hypotheses are supported, demonstrating that students' positive perceptions of VR, ranging from perceived usefulness, motivation, and engagement to learning outcomes contribute significantly to their intention to continue using VR in learning. The final results of this analysis are illustrated in Figure 1, which presents the SEM model diagram.

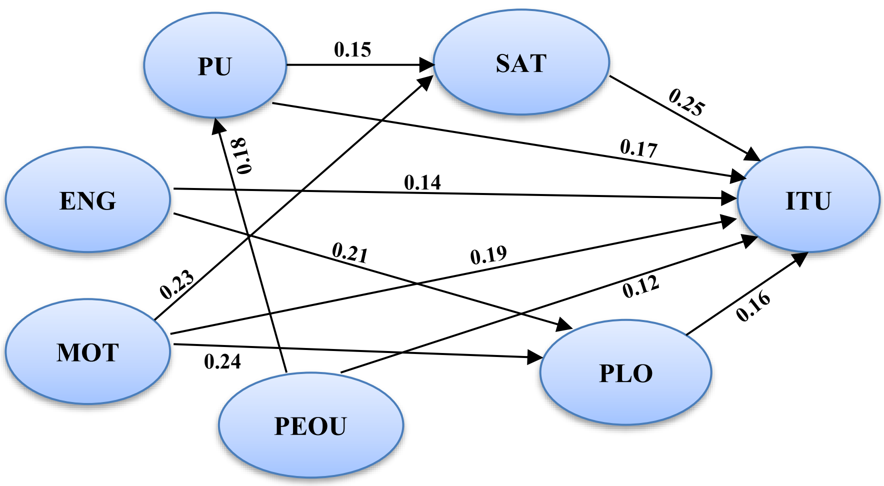

Figure 1. SEM Model

3.2. Virtual Reality as a Catalyst for the Revolution in Biomedical Education

VR has emerged as a disruptive technology capable of revolutionizing teaching methods in biomedical education, particularly in the learning of anatomy and physiology. This technology enables students to explore human body structures in an immersive, interactive, and realistic three-dimensional environment. It significantly reduces reliance on conventional methods such as textbooks or plastic anatomical models. As a result, students are able to develop a more accurate spatial understanding of organs and body systems.

In this study, preliminary findings indicate that students perceive VR as highly beneficial in supporting their learning process. Respondents reported that the use of VR enhanced their focus, engagement, and clarified complex structures that are difficult to understand through traditional methods. This approach is consistent with findings in the literature, such as the study by Sung et al., (2024), which stated that VR enhances cognitive effectiveness and information retention in health education. This is further supported by Wu et al. (2022) and Díaz González et al. (2025), who found that VR not only adds aesthetic value to learning but also improves the quality of conceptual understanding.

The integration of VR into the biomedical curriculum also reflects a paradigm shift from passive learning to experiential, active learning. In a VR environment, students are not merely observing or reading; they actively experience real-time physiological simulations, such as blood flow or organ function. This creates a more authentic and reflective learning environment, aligning with Vygotsky's constructivist theory and technology-enhanced learning approaches (Rigopouli et al., 2025). It demonstrates that VR supports the development of critical thinking and problem-solving skills, which are essential in today's digital era.

The role of VR as a catalyst for educational transformation is evident in the growing student intention to use this technology sustainably. Students no longer view VR merely as a supplementary learning tool, but as an integral part of the modern educational technology ecosystem that should be permanently integrated. This reflects a shift in perception from viewing technology as a "complement" to recognizing it as a "necessity."

3.3. Students' Perceptions of the Usefulness of Virtual Reality

Perceived usefulness (PU) is one of the core constructs in technology adoption models, measuring the extent to which users believe that using a system will enhance their performance (Hussain et al., 2025). In the context of this study, PU refers to the degree to which students believe that VR technology provides tangible benefits in learning anatomy and physiology. SEM analysis results indicate that PU has a significant influence on students' intention to continue using VR (ITU), as reflected in the support for Hypothesis H2. This finding suggests that perceptions of usefulness play a crucial role in shaping students' decisions to adopt and sustain the use of VR in their learning processes.

The findings of this study indicate that many respondents stated VR helped them understand complex topics such as the nervous system, internal organs, and the spatial relationships between anatomical structures. These results are supported by Cheng & Tsai (2020), who found that students who perceived VR as useful were more likely to be motivated to use the technology again in the future. Realistic 3D visualizations, the ability to interact with anatomical objects virtually, and the active, immersive learning experience are key factors that strengthen this perception of usefulness. According to Georgiou et al. (2021), VR technology is not only visually engaging but also adds significant value to conceptual understanding.

In addition to influencing the intention to use, students' perceptions of the usefulness of VR were also found to have a significant impact on their learning satisfaction, as confirmed by the results of Hypothesis H7. Students who perceived VR as helpful in improving their learning reported greater overall satisfaction with their learning experience. This satisfaction reflects the fulfillment of academic expectations, ease of understanding the material, and increased confidence in mastering topics in anatomy and physiology. The perception of usefulness not only promotes continued use of VR but also enhances students' overall perception of the quality of their learning experience.

These findings are consistent with previous studies, such as those by Cohen et al. (2022) and Bansah & Darko Agyei (2022), which identified students' perceptions of usefulness as a strong predictor in the adoption of immersive technologies in education. In the context of biomedical education, the usefulness of VR becomes even more critical due to the high complexity of the content and limited access to hands-on practice. Therefore, students' perception of VR as a tool that enhances learning outcomes serves as a key foundation for designing long-term implementation strategies. Educational institutions should respond to this perception by providing adequate technical support and optimal curriculum integration.

3.4. Ease of Use: An Indirect Influence on Usage Intention

Perceived ease of use (PEOU) in the technology acceptance model refers to the degree to which a person believes that using a particular technology requires minimal effort (F. Huang et al., 2022; Liesa-Orús et al., 2023). In this study, PEOU measures students' perceptions of how easy it is to access and use VR applications in learning anatomy and physiology. Based on the SEM analysis, the direct effect of PEOU on Intention to Use (ITU) was not significant, leading to the rejection of Hypothesis H3. However, PEOU showed a positive and significant effect on perceived usefulness (PU), thereby supporting Hypothesis H8.

The findings of this study suggest that students do not consider ease of use as the primary reason for deciding whether they would use VR again. Instead, ease of use plays a more indirect role by shaping the perception that VR is useful, which in turn drives the intention to use it. In other words, students may view ease of use as a supporting factor for learning effectiveness, rather than a key determinant in their decision to adopt the technology. The perception of academic value tends to outweigh the perception of convenience in the context of learning with innovative technologies. According to Alhammadi, (2021), students are more likely to prioritize learning outcomes over technical comfort. This contrasts with everyday technologies, such as in the study by An et al. (2023) on mobile applications, where user convenience tends to be the primary driver of continued use.

This finding aligns with the revised Technology Acceptance Model (Y.-C. Huang et al., 2023), which suggests that PEOU often does not have a direct impact on behavioral intention when the technology in question is complex and used in professional contexts. In the implementation of VR in biomedical education, institutions should still provide initial training and technical guidance, but they need not be overly concerned if the technology is not entirely intuitive, as long as students perceive tangible benefits from its use. This highlights a crucial insight: when the value is clear, users are willing to overcome technical challenges to achieve meaningful learning outcomes.

3.5. Student Motivation as a Key Driver of Intention and Satisfaction

Learning motivation is a key psychological factor that drives students to explore and adopt new learning methods (Dahri et al., 2024; Sayaf et al., 2022), including VR technology. In this study, motivation was measured based on internal drives such as curiosity, enthusiasm for understanding complex concepts, and interest in technological innovation. The SEM analysis revealed that motivation has a significant impact on both the intention to use VR (Hypothesis H5) and student satisfaction in the learning process (Hypothesis H9). These findings reinforce the view that motivation serves as a primary driver in students' decisions to adopt new technologies.

The results of this study indicate that students with high levels of motivation tend to show enthusiasm in using VR, even if they are not yet fully familiar with the technology. Supported by studies from Nguyen (2021) and Lin & Wang (2021), students' intrinsic motivation can help overcome barriers to adopting new technologies, driven by a desire for more enjoyable and interactive learning experiences. Students perceive VR not merely as a visual aid, but as an opportunity to expand their learning through more contextual and practical approaches. Motivation serves as a critical bridge between technology acceptance and academic achievement.

According to Hettiarachchi et al. (2021), Naseer & Rafique (2021), and Rahman et al. (2021) motivation contributes to students' learning satisfaction. In this context, our study found that students who felt challenged and inspired by advanced technology tended to have a more positive and fulfilling learning experience. They were more open to new approaches, more actively engaged in the learning process, and perceived their learning experience as more meaningful. This satisfaction stemmed not only from academic outcomes, but also from the emotional experience they encountered while using VR to understand human body structures and functions.

Our research findings align with motivation theory in education, particularly the Self-Determination Theory (Guay, 2022). This theory posits that intrinsically motivated individuals are more likely to persist in using new technologies or methods because they feel a sense of autonomy and purpose. In the context of biomedical education, VR offers visual stimuli and cognitive challenges that resonate with learners who possess a high level of curiosity. Therefore, educational institutions should not only provide access to technology but also foster motivational aspects by designing engaging and relevant learning experiences.

3.6. Student Engagement and Its Impact on Learning Outcomes

Student engagement is one of the key indicators in assessing the success of implementing technology-based learning methods such as VR ((Rafiq et al., 2022; Solé-Beteta et al., 2022). In the context of this study, engagement was measured through students' concentration, focus, and active participation during the learning process. Based on the results of the SEM analysis, engagement had a significant direct effect on both intention to use (ITU) and perceived learning outcome (PLO), supporting hypotheses H4 and H10. These findings indicate that the higher the level of student engagement in the VR learning process, the greater the likelihood that they will continue using the technology and perceive tangible learning benefits.

Students who feel actively engaged in learning sessions tend to experience increased attention and enthusiasm (Bruggeman et al., 2022; Chans & Portuguez Castro, 2021; Dewaele & Li, 2021). Through VR, students are not merely passive recipients of information but also directly interact with learning content in a realistic three-dimensional format. This enhances their ability to understand and retain information, particularly complex material such as organ structures and the functions of physiological systems. Thus, engagement serves as a critical bridge between the design of educational technology and the achievement of improved learning outcomes. VR functions not only as a visual aid but also as an interactive medium that creates a dynamic and challenging learning environment. The positive student experience fosters sustained motivation for students to learn and innovate throughout their academic journey.

These findings are supported by the views of Goi (2024) and the study by Yang et al. (2023), which state that emotional and cognitive engagement in VR-based learning is strongly correlated with improved learning outcomes. In the digital education era, passive traditional approaches are increasingly being abandoned as they fail to sustain students' attention over time. Technologies such as VR offer a strategic solution to enhance student engagement through visual, exploratory, and interactive methods. With high levels of engagement, students not only learn more effectively but also build emotional connections with the subject matter.

3.7. Perceived Learning Outcomes as a Predictor of Intention to Use

Perceived learning outcome (PLO) reflects the extent to which students feel they have gained meaningful understanding and knowledge (Chou et al., 2024; Tzafilkou et al., 2021; Wei et al., 2023). In this study, the SEM results indicate that PLO has a significant effect on intention to use (ITU), thereby supporting hypothesis H6. This means that the more students perceive they are learning better through VR, the stronger their intention to continue using it in the learning process. These findings suggest that the perception of academic success serves as a strong driver for the continued adoption of innovative technologies such as VR.

Students who feel capable of understanding body structures, organ functions, and system interactions more clearly through VR media tend to develop greater confidence in the effectiveness of this method. They perceive that VR offers visual advantages and hands-on experiences not available in conventional methods such as textbooks or presentation slides. Their success in grasping complex concepts through this visual and interactive approach reinforces their motivation to continue using VR. This perception of learning outcomes fosters a belief that the technology is worth integrating into the learning process.

The findings of this study are supported by constructivist learning theory (Almulla, 2023), which emphasizes the importance of active engagement in constructing knowledge through direct experience. When using VR, students do not merely receive information, but actively develop understanding through exploration and interaction with three-dimensional digital content. This approach enhances cognitive reinforcement by simultaneously integrating visual, spatial, and conceptual information. According to Meisuri et al. (2023) and Marks & Thomas (2022), the greater the perceived learning experience, the stronger the drive to reuse the technology in the future. The successful adoption of VR in biomedical education depends not only on the sophistication of the technology, but also on students' perceptions of the effectiveness of the learning it provides.

3.8. Student Satisfaction as a Mediator between Perception and Intention

Student satisfaction reflects a learning experience that is perceived as enjoyable, beneficial, and aligned with expectations (Alqahtani et al., 2022; Kanwar & Sanjeeva, 2022). In this study, the results of the SEM analysis indicate that satisfaction has a significant influence on the intention to use VR in the future, supporting hypothesis H7. This suggests that students who are satisfied with the use of VR in learning anatomy and physiology tend to have a stronger intention to continue using it. Satisfaction here serves as a key mediating variable between perceived usefulness (PU) and the long-term decision to adopt the technology.

Students who are satisfied with their VR learning experience generally describe the technology as engaging, efficient, and helpful in understanding complex material. They feel that the learning process becomes more enjoyable and less monotonous, particularly due to the presence of interactive visual simulations and exploration of three-dimensional spaces. This positive experience reinforces the perception that VR is not just a learning aid, but also an educational innovation that enhances the quality of learning. Therefore, satisfaction acts as an emotional driving factor in fostering loyalty toward the continued use of VR.

Within the framework of technology adoption theory, satisfaction functions as a reinforcer of sustained behavior (Alyoussef & Omer, 2023; Granić, 2024). When students feel satisfied, they are more likely to recommend VR to peers, be open to further training, and be willing to incorporate VR as part of their learning strategy. This also explains why the influence of perceived usefulness (PU) on intention to use (ITU) is indirectly strengthened through satisfaction (SAT). In other words, perceived usefulness alone is not sufficient; it is the actual experience and satisfaction felt by students that serve as the key to ensuring the continued use of the technology.

3.9. Implications for the Development of Biomedical Education

The findings of this study provide strong evidence that VR technology holds great potential in revolutionizing learning tools for anatomy and physiology. With high levels of student engagement, satisfaction, and perceived learning outcomes, VR can be strategically integrated into biomedical curriculum development. Traditional curricula based on text and two-dimensional illustrations should be complemented or replaced with more visual, interactive, and experience-based approaches. The widespread and structured implementation of VR requires supportive institutional policies, including faculty training, infrastructure provision, and curriculum integration aligned with learning outcomes. By adopting this approach, educational institutions not only enhance academic quality but also better prepare students for entering an increasingly digital and high-tech medical world.

4. CONCLUSION

This study demonstrates that Virtual Reality (VR) technology holds substantial potential in revolutionizing the teaching of anatomy and physiology within biomedical education. Findings from the Structural Equation Modeling (SEM) analysis reveal that students' perceptions of usefulness, motivation, engagement, and perceived learning outcomes significantly influence their intention to use VR in the future. Student satisfaction also emerges as a critical mediating variable, bridging the perception of usefulness with the willingness to continue utilizing this technology. Meanwhile, ease of use exerts an indirect effect, suggesting that students prioritize the effectiveness of the technology over mere convenience when evaluating new learning tools.

An interactive, enjoyable, and meaningful learning experience via VR has been shown to enhance student motivation, comprehension of complex concepts, and sustained intention to adopt technology in educational processes. The primary contribution of this study lies in offering empirical evidence for educational institutions to consider broader integration of VR into biomedical curricula. By promoting a visual and exploratory approach that aligns with the learning preferences of the digital generation, VR can serve as a catalyst for more effective, participatory, and relevant learning in the digital education era.

The limitations of this study include a sample size that may not fully represent the broader student population within a given country. Additionally, the quantitative approach employed does not comprehensively capture the nuanced dynamics of students' experiences, such as barriers to technology use. Future research is recommended to adopt a qualitative approach, such as in-depth interviews or focus group discussions, to gain a more contextualized understanding. Experimental studies are also encouraged to directly assess the impact of VR on academic performance improvement.

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REFERENCES

Al-Hor, M., Almahdi, H., Al-Theyab, M., Mustafa, A. G., Seed Ahmed, M., & Zaqout, S. (2024). Exploring student perceptions on virtual reality in anatomy education: insights on enjoyment, effectiveness, and preferences. *BMC Medical Education*, *24*(1), 1405. https://doi.org/10.1186/s12909-024-06370-6

Alhammadi, S. (2021). The Effect of the COVID-19 Pandemic on Learning Quality and Practices in Higher Education—Using Deep and Surface Approaches. *Education Sciences*, *11*(9), 462. https://doi.org/10.3390/educsci11090462

Almulla, M. A. (2023). Constructivism learning theory: A paradigm for students' critical thinking, creativity, and problem solving to affect academic performance in higher education. *Cogent Education*, *10*(1). https://doi.org/10.1080/2331186X.2023.2172929

Alqahtani, M. A., Alamri, M. M., Sayaf, A. M., & Al-Rahmi, W. M. (2022). Exploring student satisfaction and acceptance of e-learning technologies in Saudi higher education. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.939336

Alturkustani, S., Durfee, A., O'Leary, O. F., O'Mahony, S. M., O'Mahony, C., Lone, M., & Factor, A. (2025). Measuring students' perceptions of virtual reality for learning anatomy using the general extended technology acceptance model for E-learning. *Anatomical Sciences Education*, *18*(6), 579–595. https://doi.org/10.1002/ase.70045

Alyoussef, I. Y., & Omer, O. M. A. (2023). Investigating Student Satisfaction and Adoption of Technology-Enhanced Learning to Improve Educational Outcomes in Saudi Higher Education. *Sustainability*, *15*(19), 14617. https://doi.org/10.3390/su151914617

An, S., Eck, T., & Yim, H. (2023). Understanding Consumers' Acceptance Intention to Use Mobile Food Delivery Applications through an Extended Technology Acceptance Model. *Sustainability*, *15*(1), 832. https://doi.org/10.3390/su15010832

Bansah, A. K., & Darko Agyei, D. (2022). Perceived convenience, usefulness, effectiveness and user acceptance of information technology: evaluating students' experiences of a Learning Management System. *Technology, Pedagogy and Education*, *31*(4), 431–449. https://doi.org/10.1080/1475939X.2022.2027267

Bruggeman, B., Garone, A., Struyven, K., Pynoo, B., & Tondeur, J. (2022). Exploring university teachers' online education during COVID-19: Tensions between enthusiasm and stress. *Computers and*

Education Open, *3*, 100095. https://doi.org/10.1016/j.caeo.2022.100095

Chans, G. M., & Portuguez Castro, M. (2021). Gamification as a Strategy to Increase Motivation and Engagement in Higher Education Chemistry Students. *Computers*, *10*(10), 132. https://doi.org/10.3390/computers10100132

Cheng, K., & Tsai, C. (2020). Students' motivational beliefs and strategies, perceived immersion and attitudes towards science learning with immersive virtual reality: A partial least squares analysis. *British Journal of Educational Technology*, *51*(6), 2140–2159. https://doi.org/10.1111/bjet.12956

Chou, S.-W., Hsieh, M.-C., & Pan, H.-C. (2024). Understanding the impact of self-regulation on perceived learning outcomes based on social cognitive theory. *Behaviour & Information Technology*, *43*(6), 1129–1148. https://doi.org/10.1080/0144929X.2023.2198048

Cohen, A., Soffer, T., & Henderson, M. (2022). Students' use of technology and their perceptions of its usefulness in higher education: International comparison. *Journal of Computer Assisted Learning*, *38*(5), 1321–1331. https://doi.org/10.1111/jcal.12678

Dahri, N. A., Yahaya, N., Al-Rahmi, W. M., Noman, H. A., Alblehai, F., Kamin, Y. Bin, Soomro, R. B., Shutaleva, A., & Al-Adwan, A. S. (2024). Investigating the motivating factors that influence the adoption of blended learning for teachers' professional development. *Heliyon*, *10*(15), e34900. https://doi.org/10.1016/j.heliyon.2024.e34900

Dewaele, J.-M., & Li, C. (2021). Teacher enthusiasm and students' social-behavioral learning engagement: The mediating role of student enjoyment and boredom in Chinese EFL classes. *Language Teaching Research*, *25*(6), 922–945. https://doi.org/10.1177/13621688211014538

Dhar, P., Rocks, T., Samarasinghe, R. M., Stephenson, G., & Smith, C. (2021). Augmented reality in medical education: students' experiences and learning outcomes. *Medical Education Online*, *26*(1). https://doi.org/10.1080/10872981.2021.1953953

Díaz González, E. M., Belaroussi, R., Soto-Martín, O., Acosta, M., & Martín-Gutierrez, J. (2025). Effect of Interactive Virtual Reality on the Teaching of Conceptual Design in Engineering and Architecture Fields. *Applied Sciences*, *15*(8), 4205. https://doi.org/10.3390/app15084205

Georgiou, Y., Tsivitanidou, O., & Ioannou, A. (2021). Learning experience design with immersive virtual reality in physics education. *Educational Technology Research and Development*, *69*(6), 3051–3080. https://doi.org/10.1007/s11423-021-10055-y

Goi, C. L. (2024). The Impact of VR-Based Learning on Student Engagement and Learning Outcomes in Higher Education. In C. L. Goi (Ed.), *Teaching and Learning for a Sustainable Future: Innovative Strategies and Best Practices* (pp. 207–223). https://doi.org/10.4018/978-1-6684-9859-0.ch012

Granić, A. (2024). Technology adoption at individual level: toward an integrated overview. *Universal Access in the Information Society*, *23*(2), 843–858. https://doi.org/10.1007/s10209-023-00974-3

Guay, F. (2022). Applying Self-Determination Theory to Education: Regulations Types, Psychological Needs, and Autonomy Supporting Behaviors. *Canadian Journal of School Psychology*, *37*(1), 75–92. https://doi.org/10.1177/08295735211055355

Guo, X., Liu, Y., Tan, Y., Xia, Z., & Fu, H. (2024). Hazard identification performance comparison between virtual reality and traditional construction safety training modes for different learning style individuals. *Safety Science*, *180*, 106644. https://doi.org/10.1016/j.ssci.2024.106644

Hettiarachchi, S., Damayanthi, B., Heenkenda, S., Dissanayake, D., Ranagalage, M., & Ananda, L. (2021). Student Satisfaction with Online Learning during the COVID-19 Pandemic: A Study at State Universities in Sri Lanka. *Sustainability*, *13*(21), 11749. https://doi.org/10.3390/su132111749

Huang, F., Teo, T., & Scherer, R. (2022). Investigating the antecedents of university students' perceived ease of using the Internet for learning. *Interactive Learning Environments*, *30*(6), 1060–1076. https://doi.org/10.1080/10494820.2019.1710540

Huang, Y.-C., Li, L.-N., Lee, H.-Y., Browning, M. H. E. M., & Yu, C.-P. (2023). Surfing in virtual reality: An application of extended technology acceptance model with flow theory. *Computers in Human Behavior Reports*, *9*, 100252. https://doi.org/10.1016/j.chbr.2022.100252

Hussain, A., Zhiqiang, M., Li, M., Jameel, A., Kanwel, S., Ahmad, S., & Ge, B. (2025). The mediating effects of perceived usefulness and perceived ease of use on nurses' intentions to adopt advanced technology. *BMC Nursing*, *24*(1), 33. https://doi.org/10.1186/s12912-024-02648-8

Iqbal, A. I., Aamir, A., Hammad, A., Hafsa, H., Basit, A., Oduoye, M. O., Anis, M. W., Ahmed, S., Younus, M. I., & Jabeen, S. (2024). Immersive Technologies in Healthcare: An In-Depth Exploration of Virtual Reality and Augmented Reality in Enhancing Patient Care, Medical Education, and Training Paradigms. *Journal of Primary Care & Community Health*, *15*. https://doi.org/10.1177/21501319241293311

Jiang, J., & Fryer, L. K. (2024). The effect of virtual reality learning on students' motivation: A scoping review. *Journal of Computer Assisted Learning*, *40*(1), 360–373. https://doi.org/10.1111/jcal.12885

Kanwar, A., & Sanjeeva, M. (2022). Student satisfaction survey: a key for quality improvement in the higher education institution. *Journal of Innovation and Entrepreneurship*, *11*(1), 27. https://doi.org/10.1186/s13731-022-00196-6

Korkut, E. H., & Surer, E. (2023). Visualization in virtual reality: a systematic review. *Virtual Reality*, *27*(2), 1447–1480. https://doi.org/10.1007/s10055-023-00753-8

Liesa-Orús, M., Latorre-Cosculluela, C., Sierra-Sánchez, V., & Vázquez-Toledo, S. (2023). Links between ease of use, perceived usefulness and attitudes towards technology in older people in university: A structural equation modelling approach. *Education and Information Technologies*, *28*(3), 2419–2436. https://doi.org/10.1007/s10639-022-11292-1

Lin, Y.-J., & Wang, H. (2021). Using virtual reality to facilitate learners' creative self-efficacy and intrinsic motivation in an EFL classroom. *Education and Information Technologies*, *26*(4), 4487–4505. https://doi.org/10.1007/s10639-021-10472-9

Luik, P., & Taimalu, M. (2021). Predicting the Intention to Use Technology in Education among Student Teachers: A Path Analysis. *Education Sciences*, *11*(9), 564. https://doi.org/10.3390/educsci11090564

Lv, N., & Gong, J. (2022). The application of virtual reality technology in the efficiency optimisation of students' online interactive learning. *International Journal of Continuing Engineering Education and Life-Long Learning*, *32*(1), 35. https://doi.org/10.1504/IJCEELL.2022.121218

Marks, B., & Thomas, J. (2022). Adoption of virtual reality technology in higher education: An evaluation of five teaching semesters in a purpose-designed laboratory. *Education and Information Technologies*, *27*(1), 1287–1305. https://doi.org/10.1007/s10639-021-10653-6

Marougkas, A., Troussas, C., Krouska, A., & Sgouropoulou, C. (2023). Virtual Reality in Education: A Review of Learning Theories, Approaches and Methodologies for the Last Decade. *Electronics*, *12*(13), 2832. https://doi.org/10.3390/electronics12132832

Meisuri, M., Nuswantoro, P., Mardikawati, B., & Judijanto, L. (2023). Technology Revolution in Learning: Building the Future of Education. *Journal of Social Science Utilizing Technology*, *1*(4), 214–226. https://doi.org/10.70177/jssut.v1i4.660

Moro, C., Birt, J., Stromberga, Z., Phelps, C., Clark, J., Glasziou, P., & Scott, A. M. (2021). Virtual and Augmented Reality Enhancements to Medical and Science Student Physiology and Anatomy Test Performance: A Systematic Review and Meta-Analysis. *Anatomical Sciences Education*, *14*(3), 368–376. https://doi.org/10.1002/ase.2049

Mustafa, A. S., & Garcia, M. B. (2021). Theories Integrated With Technology Acceptance Model (TAM) in Online Learning Acceptance and Continuance Intention: A Systematic Review. *2021 1st Conference on Online Teaching for Mobile Education (OT4ME)*, 68–72. https://doi.org/10.1109/OT4ME53559.2021.9638934

Naseer, S., & Rafique, S. (2021). Moderating Role of Teachers' Academic Support between Students' Satisfaction with Online Learning and Academic Motivation in Undergraduate Students during COVID-19. *Education Research International*, *2021*, 1–9. https://doi.org/10.1155/2021/7345579

Nguyen, H.-T. T. (2021). Boosting Motivation to Help Students to Overcome Online Learning Barriers in Covid-19 Pandemic: A Case study. *International Journal of Interactive Mobile Technologies (IJIM)*, *15*(10), 4. https://doi.org/10.3991/ijim.v15i10.20319

Pandita, A., & Kiran, R. (2023). The Technology Interface and Student Engagement Are Significant Stimuli in Sustainable Student Satisfaction. *Sustainability*, *15*(10), 7923. https://doi.org/10.3390/su15107923

Pettersson, A. F., Karlgren, K., Al-Saadi, J., Hjelmqvist, H., Meister, B., Zeberg, H., & Silén, C. (2023). How students discern anatomical structures using digital three-dimensional visualizations in anatomy education. *Anatomical Sciences Education*, *16*(3), 452–464. https://doi.org/10.1002/ase.2255

Rafiq, A. A., Triyono, M. B., & Djatmiko, I. W. (2022). Enhancing student engagement in vocational education by using virtual reality. *Waikato Journal of Education*, *27*(3), 175–188. https://doi.org/10.15663/wje.v27i3.964

Rahman, M. H. A., Uddin, M. S., & Dey, A. (2021). Investigating the mediating role of online learning motivation in the COVID-19 pandemic situation in Bangladesh. *Journal of Computer Assisted Learning*, *37*(6), 1513–1527. https://doi.org/10.1111/jcal.12535

Rigopouli, K., Kotsifakos, D., & Psaromiligkos, Y. (2025). Vygotsky's Creativity Options and Ideas in 21st-Century Technology-Enhanced Learning Design. *Education Sciences*, *15*(2), 257. https://doi.org/10.3390/educsci15020257

Sayaf, A. M., Alamri, M. M., Alqahtani, M. A., & Alrahmi, W. M. (2022). Factors Influencing University Students' Adoption of Digital Learning Technology in Teaching and Learning. *Sustainability*, *14*(1), 493. https://doi.org/10.3390/su14010493

Sinha, S., DeYoung, V., Nehru, A., Brewer-Deluce, D., & Wainman, B. C. (2022). Determinants of Learning Anatomy in an Immersive Virtual Reality Environment — A Scoping Review. *Medical Science Educator*, *33*(1), 287–297. https://doi.org/10.1007/s40670-022-01701-y

Solé-Beteta, X., Navarro, J., Gajšek, B., Guadagni, A., & Zaballos, A. (2022). A Data-Driven Approach to Quantify and Measure Students' Engagement in Synchronous Virtual Learning Environments. *Sensors*, *22*(9), 3294. https://doi.org/10.3390/s22093294

Sung, H., Kim, M., Park, J., Shin, N., & Han, Y. (2024). Effectiveness of Virtual Reality in Healthcare Education: Systematic Review and Meta-Analysis. *Sustainability*, *16*(19), 8520. https://doi.org/10.3390/su16198520

Tzafilkou, K., Perifanou, M., & Economides, A. A. (2021). Negative emotions, cognitive load, acceptance, and self-perceived learning outcome in emergency remote education during COVID-19. *Education and Information Technologies*, *26*(6), 7497–7521. https://doi.org/10.1007/s10639-021-10604-1

Wei, X., Saab, N., & Admiraal, W. (2023). Do learners share the same perceived learning outcomes in MOOCs? Identifying the role of motivation, perceived learning support, learning engagement, and self-regulated learning strategies. *The Internet and Higher Education*, *56*, 100880. https://doi.org/10.1016/j.iheduc.2022.100880

Wekerle, C., Daumiller, M., & Kollar, I. (2022). Using digital technology to promote higher education learning: The importance of different learning activities and their relations to learning outcomes. *Journal of Research on Technology in Education*, *54*(1), 1–17. https://doi.org/10.1080/15391523.2020.1799455

Wong, E. Y., Hui, R. T., & Kong, H. (2023). Perceived usefulness of, engagement with, and effectiveness of virtual reality environments in learning industrial operations: the moderating role of openness to experience. *Virtual Reality*, *27*(3), 2149–2165. https://doi.org/10.1007/s10055-023-00793-0

Wu, W., Zhao, Z., Du, A., & Lin, J. (2022). Effects of Multisensory Integration through Spherical Video-Based Immersive Virtual Reality on Students' Learning Performances in a Landscape Architecture Conservation Course. *Sustainability*, *14*(24), 16891. https://doi.org/10.3390/su142416891

Yang, H., Cai, M., Diao, Y., Liu, R., Liu, L., & Xiang, Q. (2023). How does interactive virtual reality enhance learning outcomes via emotional experiences? A structural equation modeling approach. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.1081372

Yu, Z., & Xu, W. (2022). A meta-analysis and systematic review of the effect of virtual reality technology on users' learning outcomes. *Computer Applications in Engineering Education*, *30*(5), 1470–1484. https://doi.org/10.1002/cae.22532